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PASTEUR: A STUDY IN GREATNESS

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GREATNESS is a matter of judgment. The degree of worth accorded anything whatsoever is determined solely by the intellectual and moral content of the individual, or the age, that plays the rôle of judge. We speak of great architects, musicians, orators, painters, poets, sculptors, soldiers, statesmen; and cite as examples such men as Wrenn, Beethoven, Demosthenes, Raphael, Homer, Angelo, Cæsar, Bismarck. These men, I say, were great. Why do I say so? Well, the world has pronounced them great. But you ask me, "Have you no grounds for formulating an opinion of your own?" Oh, yes, I have heard rendered the music of many composers; seen the masterpieces of many artists, and so on. And the achievements of none appear to me to surpass those of the men whose names I have mentioned. Perhaps you would name another in each line whom you hold to be more illustrious. You ask me then—"Is there no objective absolute standard by which the achievements of men may be definitely measured?" I answer "None."

You stand before Michel Angelo's "Moses" in the church of St. Peter *in vinculo* at Rome. "This" (you say) "is the finest statue in the world!" Please enlighten me as to the manner by which you have reached your decision. I grant at once that the judgment of the critics coincides with yours; but, of course, you are uninfluenced by that fact. "Is it" (I ask you) "because the statue is a true representation of a real person and event?" You answer—"No, oh no! But it seems to me that a man who dared the wrath of the most powerful potentate in the world; who wrestled with desert, and famine, and pestilence to shape the beginnings of a nation; who talked face to face with God—would have looked like that!" Ah, now you have found *the standard of greatness;* and you perceive that it is an ideal thing.

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This being true, is it not remarkable that such unanimity of agreement should have resulted from its application? It appears to predicate the existence of a racial concept of greatness. Undoubtedly this racial idea exists. Philosophers of esthetics have troubled themselves not a little to account for its origination. While considering this elusory problem, the following solution has occurred to me. I offer it as an hypothesis.

An investigation of the specific works accomplished by men ranked great reveals a curious fundamental similarity: *They all relate to the heroic.* That is to say they are either actual deeds which relieved an individual, a community or a nation from danger, or they commemorate such deeds in a masterly way. The favorite theme of poets has always been "*arms, and the man.*" And painters and sculptors have immortalized men whose acts furnish the implied answer to the query of brave Horatius, the keeper of the gate:

> **How can a man die better than by facing fearful odds,**
> **For the ashes of his fathers and the altars of his gods?**

By this analysis, the statesman is but the warrior who, with *intellect* as weapon, defends his nation.

If we consider the evolution of human society, it is not difficult to understand how this conception of greatness has grown up and established itself in the subconscious racial mind.

Back yonder in the gray and murky dawn of time, man was not that we see him to-day. Then, indeed, the conditions were exactly reversed; and man—puny, naked, defenceless—cowered in caves, or wandered miserably about seeking the sustenance which his nature demanded, but for the winning of which he was more illy equipped than the beetle that he crushed beneath his heel. Behind every rock, in every bunch of herbage, in every stream and pool, in the air he breathed, in the clouds that rolled above his head, in the glare of the sun, and in the gloom of night lurked death and a thousand dismal terrors.

That the human species escaped extermination at its very beginning is a marvel, and due solely to the one point wherein man is superior to other animals, namely, greater development of the frontal brain wherein lie the centers of memory and language. In that primitive society were some who remembered what things were good for food and where to be found; and so provided against death by poison and famine. Some devised protection against carnivorous animals or enemies of their own kind. These became *head men.* And, on account of their superior knowledge or prowess, they were esteemed while living and revered when dead. The memory of their deeds lived after them in song and story. And so they were gradually transformed from men into heroes and, later, into gods.

Oliver Wendell Holmes, alluding to the influence of heredity, said

"We are but stage-coaches in which all of our ancestors ride." By listening attentively we can hear at any time "ancestral voices prophesying war." This is why the heroic, in act or representation, moves us so profoundly. And this is my explanation of our *racial ideal of greatness.*

The man whose life sketch I now lay before you differed apparently from the traditional hero as widely as the dove from the eagle. He was no sower of dragon's teeth. Instead of sending sword and fire on every side, life, health and prosperity attended his career as the beneficent effects of light accompany the sun. And yet the recital of his bloodless wars and peaceful victories touches the same chords and thrills us with the same emotions as do the exploits of an Alexander.

Louis Pasteur was born at the village of Arbois, near Dole, in the province of Jura, France, on the twenty-seventh day of December, 1822. He died at St. Cloud, near Paris, on the twenty-eighth of September, 1895.

Like Napoleon, Pasteur was the first *ancestor* of his stock. His grandfather was a serf who purchased his own freedom. His father was a tanner who rose to no higher rank than sergeant in the service of the first consul. But he was a man of ability and fine instincts. Believing in the capability of his child to achieve something in the world, he studied diligently in order to assist the lad with his primary studies, and conducted his household with an economy that touched closely upon sacrifice that thereby a collegiate education might be made available for his son.

At fourteen, Pasteur was sent to College of Besançon. He remained there but a half year. Translated suddenly to a wholly strange environment, the shy country boy suffered so much from homesickness that he made little progress in his studies; and his health became so affected that his life was actually endangered. His father was compelled to bring him home. And now for the first time the self denial which had been practised on his account became apparent to the youth. Filled with an agony of shame that he should have so illy requited the love of his family, he resolved that he would spare no resource of his being in an endeavor to retrieve the consequences of his childish folly. The next year he requested his father to enter him at the home college of Arbois, a rural *lycée* little better than a grammar school.

Here he studied diligently, but received no instruction in the subjects which appealed to his nature. The old master assigned to teach the sciences frankly acknowledged that he knew nothing about them. But he allowed the young student access to the limited equipment; and young Pasteur spent much time in laboriously teaching himself some of the elementary principles of physics and chemistry. His teachers considered him slow. Drawing was the only subject in which he attained "honorable mention."

However, the head-master, Romanet, appears to have possessed more discernment than the rest of the faculty; for he frequently engaged young Pasteur in private talks in which he endeavored to arouse in him the ambition to prepare for teaching as a career.

At graduation, he was offered the position of *preparation assistant* or coaching tutor to the younger pupils, a post which carried the munificent salary of 300 francs *per annum* with board and lodging. He accepted the position gladly; and, with charming modesty, expressed the conviction that the salary was much beyond his deserts.

Small as his salary was, still he managed to save out of it something to help educate his sisters. Meanwhile he worked hard on the studies required for his B.S. degree, a prerequisite to his entering the École Normale Supérieure at Paris. On this examination he was graded "mediocre" in chemistry.

Pasteur had thus far been a hard student; but he does not appear to have been an enthusiastic one till he had been for some time at the École Normale under the instruction of Balard, the discoverer of bromine, who was probably the only real teacher he ever had.

But even in this highest school for the training of professors afforded by the France of that day, the scientific equipment was so meager that only a few simple experiments were allowed for repetition by the students of chemistry. An incident in this connection will show the stuff that Pasteur was made of. Not content with being told how phosphorus is prepared, he bought some bones, calcined them, treated the calx with sulphuric acid, distilled the product with charcoal, and placed the distillate in a vial neatly labelled *phosphorus*. This was his first scientific joy. His comrades dubbed him "the laboratory pillar."

About this time he was shown a sample of a strange new acid of the same composition as tartaric acid, but manifesting strikingly different physical characteristics. His curiosity was intensely aroused.

Tartaric acid had been discovered in the "tartar" of wine casks by Scheele, of Sweden, in 1770. Thann, an Alsatian manufacturer of tartaric acid, discovered some of the anomalous variety in the output of his factory in 1825. He was unable to reproduce it. It was studied by Gay Lussac and Berzelius in 1826. The latter proposed for it the name of paratartaric acid; the former suggested that it be called racemic acid. Mitscherlich, of Berlin, in 1844 reported it as isomorphic with tartaric acid; and discovered that while the latter rotates a beam of polarized light to the right, racemic acid is inactive in this respect.

These were the facts brought to Pasteur's attention at the time when he was shown a specimen of the acid. Although immensely interested in the mystery presented by racemic acid, he put it aside, resolving to take it up when through with the final examination of his course of study, an ordeal for which he was just then preparing.

His usual examination fortune attended him upon this occasion. His classmates, who were wise in their generation, merely cramming for the test, came through with flying colors while his name appeared near the bottom of the list. And in the state examination which followed, his name was put next to the last. Apparently his not being rejected was due solely to the excellence which he displayed in the practical phase of the examination wherein the candidates went through the form of actually teaching a class. The lessons in physics and chemistry given by Pasteur caused the jury to declare "he will become an excellent teacher."

He was appointed laboratory assistant to Laurent, the first to formulate an hypothesis of the substitution of hydrogen in hydrocarbons. This theory was elaborated, and enunciated in its final form, by Dumas in 1834. At this time, Laurent was working on sodium tungstate. One day he showed his assistant, under the microscope, some crystals of this salt supposedly pure but which manifested three distinct forms of crystallization. Pasteur began at once to learn how to use the goniometer. In order to master its technique, he made elaborate measurements on *all easily crystallizable tartrates,* thus revealing the fact that his curiosity concerning the two known tartaric acids had remained lively throughout the preceding two years.

In the meantime he was working toward the doctorate, which he achieved August 23, 1847, on the strength of two small papers, the one entitled "Researches on the Saturation Capacities of Arsenious Acid: A Study of the Arsenites of Soda, Potassa and Ammonia," and the other "A Study of the Phenomena Relative to the Polarization of Liquids."

He himself said of these papers, "They are elementary, and little more than programs for future work." Again he attained but poor ranking.

He now desired to study in Germany; but poverty frustrated his plans. On March 20, 1848, he read before the Académie des Sciences a part of a paper on dimorphism which was little more than a catalogue of all known substances crystallizing in two forms. Of itself, one might say that it was almost valueless. But to the student of Pasteur's life it was a proof that his work on the tartrates was still being prosecuted; and it afforded an index pointing out the tenacious purpose and the resolute will of the man.

After a flash of republican ardor in 1848, in which he not only volunteered service but also contributed to the cause all his savings, 150 francs, he returned to his crystals, and soon had the fortune to discover hemihedrism in the tartrates, a fact that had escaped the scrutiny of Mitscherlich and of Provostaye.

So far as his investigations showed, all crystals of tartaric acid had

hemihedral faces; but he had found none on the racemates. Conceiving that this aspect of crystals might be an index of their molecular structure, he reasoned that the diverse optical behaviors of solutions of tartaric and racemic acids might be explained by a structural law. On fire with this new idea, he carefully examined a lot of tartrate crystals, and found, as he had anticipated, that each had hemi-hedral facets. He turned now to racemate crystals, expecting to find them destitute of hemihedrism. Imagine his disappointment, therefore, upon finding that here also each crystal distinctly displayed hemihedrism. But upon laboriously going over his work again he discovered a fact that had previously escaped his notice, namely, that the half-form facets of tartaric acid were all turned toward the right while those of the racemates were half right-handed and half left-handed. A new idea flashed into his mind. Carefully picking apart the two kinds of racemate crystals, he made a solution of each and, with anxious mind and throbbing heart, applied the polariscope. The solution of right-handed crystals deflected the beam to the right. They were pure tartaric acid. The solution of left-handed crystals deflected the beam to the left. They were *a new acid—lævo tartaric acid.* He mixed his solutions in equal proportions. The mixture did not affect the beam. *It was racemic acid.*

His excitement was so great that he could not look through the instrument again. Like Archimedes, he exclaimed "I have found it," and rushed into the corridor, where he met an assistant whom he embraced in a transport of joy.

This was one of the most illuminating discoveries known to the history of chemistry up to that time. Measured by its ultimate results, it is doubtless the most far-reaching discovery ever made. Developing in one direction, it was the germ of a new science—stereo-chemistry; in another it transformed medicine and agriculture from empirical practises into true sciences; and incidentally it enriched the world by a number of other discoveries of unparalleled practical value. Done at the age of twenty-five, this first great work of Pasteur's was a prophecy of that brilliant career throughout which he continued to manifest the same marvelous capacity for seeing the unseeable. It led to his appointment at once as professor of chemistry in the college of Dijon.

Finding that the duties of this position consumed all his time in teaching, he asked the government for a transfer to some place which would admit of his going on with research. Quite unexpectedly to himself, he was sent at the beginning of 1849 to the University of Strasburg to relieve Bersoz, professor of chemistry there, who desired to go to Paris.

Realizing fully the value of the vein he had discovered in tartaric acids, he directed his energies along that line. He had found out what para-tartaric, or racemic, acid *is;* but neither he nor any one else knew

its origin. He now undertook the discovery of this. In 1852 he visited all the factories of tartaric acid in Germany and Austria, endeavoring to trace the production of racemic acid to its source. He ascertained that the manufacturers generally had an idea that racemic acid was either potassium or magnesium sulphate, and consequently rejected it in the process of refining tartaric acid. This accounted for the limited quantity which had accidentally found its way to the market. As most of the tartars came from the south of Europe, and had been subjected to a preliminary rectification before shipment, it was further evident that but a moiety of racemic acid ever reached the factories. He pushed on his enquiries, visiting factories and vineyards until he positively located it in the crude tartar, where he found, as he had anticipated, that it was produced abundantly simultaneously with tartaric acid in the fermentation of wines. He wrote of this quest "Never was treasure sought, never adored beauty pursued, with greater ardor."

Having located the natural source of racemic acid, Pasteur next undertook to synthesize it from tartaric acid. This appears an easy problem in light of what every student now knows of the methods for effecting hydration, for constitutionally racemic acid differs from tartaric merely in possessing water of crystallization. In June, 1853, he was able to announce the completion of this great work, which had been accomplished by maintaining cinchona tartrate at a high temperature for several hours. This synthetic product was also optically inactive. It is known as meso-tartaric acid, and is the fourth form of the series. This research brought its author the grand prize of the Académie Française, and the ribbon of the Legion of Honor from the government.

Looking now at the tartaric acids, Pasteur's mind took a wider sweep. He saw that they were typical of all living things, which present asymmetry everywhere, and that they themselves were products of a form of life.

While engaged upon the racemates, he had found that the dextro-crystals alone were altered by fermentation, the lævo-forms remaining unchanged in the liquor. "The reason for this," said he, "can only be because this special ferment *feeds,* so to speak, more easily on the dextro-forms."

He pondered this problem long before he saw his way clear to its solution. At the same time he sought to unravel the indicated physiological significance of chemical affinities.

In September, 1854, Pasteur was appointed professor of chemistry and dean of the new faculty of sciences at Lille. Upon taking up his duties, he was greatly hampered at first by lack of facilities. The conditions which he encountered would have disheartened any other man. The scientific equipment consisted of a coke-heated stove with which his room was warmed and one student's microscope. This institution

had recently been established by the municipality for the promotion of its industries, which were largely associated with alcohol.

Pasteur at once began the study of fermentation. This was a field which lay enshrouded in darkness with the exception of one tiny ray of light. In 1836, Cagniard de Latour had remarked that yeast, the ferment of beer, was composed of cells which were capable of reproduction by a sort of budding. He expressed the opinion that this microscopic plant probably acted on sugar by some sort of vegetative effect. A similar observation was made about the same time by Schwann, of Germany.

Pasteur set himself the problem of solving the mystery of fermentation. His notes show that he commenced by projecting an hypothesis associating fermentation with the dimorphism he had discovered in tartaric acid, which must have been caused in some way, he thought, by the action of a ferment on the grape juice.

Berzelius, whose ideas then reigned supreme in chemistry, was of the opinion that fermentation is a *catalytic* process. He gave it as his opinion that what de Latour *believed* that he had seen was organic matter precipitated by the process of fermentation, presenting forms *analogous* to vegetable life. Liebig's explanation was equally mystic. He defined fermentation as "action due to influence." He held the opinion that a ferment is a mass of organized matter set free from yeast cells by their death and consequent rupture. Such matter he supposed to consist of unstable molecules which in the act of changing into new molecular arrangements liberated energy which in turn converted molecules of sugar into molecules of alcohol.

Uninfluenced by the metaphysical speculations of these great scientists, Pasteur held to the sure road of experimentation. In August, 1857, he discovered the fermentative organism which sours milk and produces lactic acid. The same year he was transferred to the École Normale Supérieure at Paris. The next year he discovered that glycerine and succinic acid are both produced simultaneously with ethel alcohol when sugar is fermented.

That Pasteur lost no implication of any phase of his researches is shown by a letter to his friend Chappuis written in January, 1860. He says: "I am hoping to mark a decisive step very soon in the celebrated question of the spontaneous generation of life. Already I could speak; but I shall require the accuracy of an arithmetical problem. I intend to attain even that." In a letter to his father, of about the same date, he says: "These results open new vistas to physiology. God grant that by my persevering labors I may bring a little stone to the frail and ill-assured edifice of our knowledge of those deep mysteries, life and death, where all our intellects have so lamentably failed."

The belief that living creatures of both usual and unusual types are

continuously being spontaneously generated about us is very ancient in origin. It originated in the superficial observations and non-scientific explanations of our ancestors, and was perpetuated by the authority of great leaders, such as Aristotle and Augustine. Aristotle, whose ideas dominated the world for two thousand years, states explicitly that living beings are generated spontaneously from decomposing carcases. St. Augustine fulminates against the atheism of any who dare deny the doctrine, and cites what he considers irrefutable proofs of it. The alchemists gave recipes for the creation of various animals. Thus, Van Helmont gravely tells us, "You need only close up a dirty shirt with a measure of wheat in order to see mice engendered in it—the strange offspring of the smell of the wheat and the animal ferment attached to the shirt."

However, the more careful observation of a later period had cast discredit upon the traditional view. Thus, it had been shown irrefutably that the stock-proof of the spontaneous generationists—the appearance of maggots in decaying organic matter—was due to the hatching of flies' eggs. But the invention of the microscope, with its revelation of millions of minute forms hitherto unsuspected, revived the doctrine.

The lapse of a year after the letters cited above enabled Pasteur to announce, "Of gases, fluids, electricity, magnetism, ozone, things known or things occult—there is nothing, in the air, conditional to life *except the germs it carries.*"

This dictum was at once fiercely attacked by the generationists who included in their party savants of European fame, the most notable being Bastian, of London. The discussion held the almost breathless attention of the newspaper-reading world, and ended some years later in Pasteur's triumphant demonstration of his thesis.

You can readily imagine that this research was not prosecuted by Pasteur because of its mere academic interest. He appended to his first paper, quoted above, this query—"What could be more desirable than to push these studies far enough to prepare the road for a series of researches into the origin of various diseases?"

In 1861 Pasteur discovered the ferment of butyric acid. In the following year he discovered the ferment of acetic acid, and showed that microbes could be distinguished into two grand classes—*aerobes* and *anaerobes.* The Academy of Sciences, which had rejected his name when offered for membership upon several previous occasions, could not longer refuse to honor a man whose fame was now world-wide. He was elected a member at the end of 1862.

The manufacturers and dealers in fermented liquors had always been subjected to annoyance and loss by their inability to make wines and beers of uniform standard and to keep them in the condition in

which they were put upon the market. Alterations were constantly taking place in these articles, due, it was supposed, to certain "diseases." Inasmuch as these wares represented a large share of the wealth of France, Pasteur was urged to investigate this matter. He commenced this research in 1864.

The ensuing year, an outbreak of cholera called his attention to that disease, and he studied it with a view to finding a bacterial cause for it, but without result. In the meantime, he was investigating a pestilence of silk worms which was proving so destructive as to threaten the silk industries of southern Europe with extinction. He was quite successful with this, and was quickly able to devise a method of combating it.

Doubtless the strain incident to the many and great investigations being simultaneously pushed by him during the three years, 1865 to 1868, was responsible for a series of paralytic shocks, the first of which struck him October 10, 1868. While thought to be hopelessly ill and incapable of rational thinking, he insisted upon dictating a method of dealing with *flacherie,* a second silkworm disease which had been discovered by him in the course of his research on the silkworm pestilence. His treatment for *flacherie* proved to be a complete success, also. He recovered from this attack, but was physically lamed for the rest of his life. Although crippled in body, the work accomplished by him during his remaining twenty-seven years was not only stupendous in amount, but of transcending importance to mankind. I doubt if the example afforded by the heroic labors of the paralyzed Pasteur can be matched from the annals of all time.

By the close of 1871, he had shown that the "diseases" of wines and beers were caused by certain bacteria, all of which might be killed without injury to the product by heating it for a few minutes at a temperature of 50°–60° C.; and that if hermetically sealed at this temperature the liquors might be preserved perfectly for an indefinite period.

These studies had now thoroughly convinced their author that all diseases are of bacterial origin—a conception, you will recall, which had first come into his mind by a flash of genius ten years before. Indeed, four years prior to this (1867), Pasteur's researches had convinced a British surgeon, Joseph Lister, of Edinburgh, of the microbic origin of those purulent infections which accompany wounds and surgical operations. And although himself unacquainted with bacteriology, he successfully devised the method of asepsis which has made his name a household word.

Before the close of 1873, Pasteur finished the solution of that great problem begun at Lille nineteen years before—*the mystery of fermentation.* It is this: Certain bacteria, living at the surface of sugary fluids cause no fermentation, because they secure the oxygen which they need

from the air. They are aerobic. But if sunk, by accident or otherwise, beneath the surface they must either perish or adapt themselves to their new environment by extracting oxygen from the nearest source of supply. This is the sugar of the solution. They are able to accomplish this but slowly at first, and the bulk of the first submerged bacteria suffocate. But reproducing rapidly by budding, ensuing generations are gradually but, for us, rapidly converted into true anaerobes, which, robbing the sugar molecules of oxygen, cause that chemical change called fermentation.

This problem solved, Pasteur was able to show from it the following results of his work: (1) Precisely what fermentation is, (2) that ferments are living organisms, (3) that every variety of fermentation is caused by a special ferment, (4) that neither bacteria nor any other life forms are spontaneously generated, (5) how to prepare culture media suitable to the growth of various bacteria, (6) how to propagate pure cultures of bacteria, (7) a basis of classification of bacteria, (8) the chemical and microscopical technique of bacteriology, (9) the cause and cure of various "diseases" of fermented liquors, (10) the cause and cure of various silkworm diseases, (11) an explanation of the mystery of the optical behavior of tartaric and racemic acids, (12) two new tartaric acids (13) how to synthesize meso-tartaric and racemic acids, (14) how to make racemic acid available to commerce.

In comparison with this great work of Pasteur's, the classic example of persevering genius—Newton's fourteen-year pondering over falling bodies—sinks into insignificance, no matter how considered, either as to time involved, the difficulties encountered, or the practical value of results obtained. Nor must one fail to note that incidentally Pasteur had beaten out a road into a *new world* and created two new sciences which were to serve as vehicles for its exploration and exploitation.

Pasteur's health had been so impaired by these arduous researches that he was now compelled to give up his professorship. As he was entirely without private resources, his colleagues exerted themselves upon his behalf, and succeeded in obtaining for him from the government, in 1874, an annual pension of 12,000 francs, the equivalent of the salary he had previously received.

His friends now urged him to abstain from work; but his genius could not endure inaction. He began the study of anthrax and feruncular diseases. While these studies were in progress, the bubonic plague appeared in Russia, and the yellow fever began to work havoc in the French colonies on the west coast of Africa and in the United States. Pasteur prepared a program of preliminary researches upon them. A paper to the Académie des Sciences presented December 30, 1878, closes with these words: "Is it not permissible to believe that a day will come when easily applied preventative means will arrest those scourges which suddenly desolate and terrify populations."

In 1879, he isolated the microbe of feruncles, and in 1880 those responsible for anthrax and chicken cholera. His studies had demonstrated the fact that every infectious disease thus far investigated was produced by a specific microbe; and, further, that such microbes cultivated under certain detrimental conditions become attenuated in pathogenic activity, still capable of producing a mild form of disease in an animal inoculated with them, but occasioning immunity to further attack. Such cultures of microbes of attenuated virus are *vaccines*.

Prophylactic vaccination had, of course, been known in an empirical way prior to this in connection with small-pox. But these researches of Pasteur's afforded the first explanation of that procedure, and in addition cast a flood of light upon the etiology of disease. They firmly established the germ theory, ushered in a scientific practise of medicine and sent to limbo a thousand pious superstitions about demoniacal possessions and the mysterious visitations of an all-wise Providence that doeth all things well. For these researches, the imperial government conferred upon him the cross and cordon of the Legion of Honor.

During the years of 1880, 1881, 1882, Pasteur gave his attention to hog cholera, rabies, pneumonia in cattle, the bubonic plague, yellow fever and typhoid fever. Of these six diseases he was able to carry to complete success his researches on the first three only. In 1881, a ship having come into Bordeaux from Senegal with several cases of yellow fever on board, he went thither, hoping for a favorable opportunity to study it at first hand. He was not permitted to do so. But his observations convinced him that this fever is not contagious.

Before the close of 1885, he had isolated the microbe of rabies, prepared its vaccine and perfected the method of treatment. This was a disease which caused not merely considerable property loss and suffering, it imbued the popular imagination with a dread but little less than the terror occasioned by a pestilence.

As despite the researches of hundreds of bacteriologists one may still hear it asserted that rabies is an imaginary disease, some statistics may not here be out of place. Accurate account of 320 cases of persons bitten by mad dogs prior to Pasteur's work in this field, showed a mortality of 40 per cent. The first 350 cases treated by his method furnished but one death, that of a little girl brought to the hospital in such condition and so late that Pasteur pronounced the case hopeless from the start, and only undertook it for humanity's sake. After the treatment had been given in 1,726 cases there had been but ten deaths.

The conquest of rabies was the last great work accomplished personally by Pasteur. Reattacked by paralysis in 1888, he could thenceforth prosecute his ideas only by the labor of other hands. But he had a host of disciples in Europe and America, some of whom had studied under his personal guidance, but many more who, without having seen

the great master, had nevertheless lighted their torches at his flame. I know of no surer index of a man's greatness than the measure of inspiration imparted by him.

Already Gayon had proved the bacterial cause of the decay of eggs. Koch had isolated the bacilli of tuberculosis and cholera. Traube had shown the like cause of ammoniacal fermentation; and upon the knowledge thus given, Van Tieghem and Gayon had devised their well-known treatment of diseases of the urinary organs. Lister had introduced asepsis, prior to which hospital statistics showed a mortality of 68 per cent. of cases of puerperal fever, gangrene and septicæmia generally incident to surgical operations. Accounts of surgical wards of army hospitals during our own civil war, typical, of course, of all that had preceded, with their perpetual agony, suppuration and horrible odors, read like a nightmare of insanity. A noted surgeon-teacher of that day said to his students, "When an operation seems necessary, think ten times about it; for too often when we decide upon an operation we sign the patient's death warrant." Another said, "He who shall conquer purulent infection will deserve a golden statue."

But to resume our catalogue: Behring and Kitasato, investigating lock-jaw, had discovered the microbe of tetanus, and ascertained the curious fact that although the patient was constitutionally affected the microbe was localized to the wound. They further found that the systemic effect of the disease was due to a toxin produced by the bacterium which was likewise fatally affected by the toxin. So that diluted solutions of the toxin not only constituted a remedy for the disease, but also a prophylaxis when administered in advance of infection. This was the first of the series of remedies known as *anti-toxins*.

Utilizing these results in the study of diphtheria, the combined labors of Richet and Herico, Roux and Yersin, Klebs and Loeffler, eventuated in 1894 in complete mastery of this disease, whose investigation had been inaugurated by Pasteur a dozen years before. Prior to the antitoxin method of treatment, diphtheria had justly been regarded as one of the worst scourges of our race, claiming a death-toll of 60 per cent. of all cases, and frequently leaving the survivors seriously injured for the remainder of their lives. At present, the mortality is about four per cent. And vaccination with the serum rendering the recipient immune to the disease for a period of about two months, epidemics of diphtheria may be entirely prevented by utilizing this prophylactic measure.

Closely connected with these researches on tetanus and diphtheria was a remarkable research brought out about this time by Metchnikoff, one of Pasteur's Russian pupils, in which he discovered the rôle of leucophytes, or white corpuscles of the blood. It appears that they constitute, so to speak, an army of defense, attacking and "eating up" in-

vading microbes, thus explaining, by the principle of auto-vaccination or auto-toxination, why an individual may at certain times be immune to contagious disease.

And here, permit a parenthetical word upon vivisection. This vast amount of research had entailed much experimentation with living animals; and, as might have been foreseen, certain false humanitarians raised a great outcry about it. In England this went so far as to lead to the enactment of an antivivisection law, since repealed, I believe, although organized societies there, and on the continent, and in America still carry on an agitation. However kind the surgeon or pathologist may be, he can not avoid inflicting some pain in his efforts to prevent more. Nor can it have escaped your observation that, no less than man, the lower animals profited from these discoveries which could not have been made in any other way. It is also worthy of note that no antivivisectionist has ever offered to sacrifice himself for the good of humanity. The colleagues of Pasteur testify that he always used anesthetics in his work on animals and at such times evinced the most acute sympathetic suffering; only the end in view gave him courage to go on with the experiment. He said of himself that he could never have the heart to shoot a bird for sport.

Pasteur's discoveries were epoch-making, and revealed in him the Copernicus of medicine. Prior to his researches, the causes and rational treatment of disease were no better understood than in the stone age. Naturally, his conclusions were not accepted by medical men till every possible opposition had been exhausted. Physicians resented instruction from a man devoid of medical training. "*A mere chemist*" was the sneer most frequently on the lips of his adversaries. When they could no longer deny the existence of microbes, adherents to the old school still vehemently asserted that they were merely an epiphenomenon. I recall a choleric colleague of my own in the faculty of a medical college where I was teaching twenty years ago, who in the heat of debate was wont to call out loudly—"Bring on your microbes. I'll eat a pint of any variety!" Fortunately for him no one took him at his word. The distinguished Professor Pettenkofer, of Munich, having made the same remark concerning Koch's bacillus of cholera, he was supplied with the beverage—and actually drank it. Heroic efforts of physicians enabled him to keep his soul between his teeth, and after recovery he had the manhood to publish an admission of error.

In 1880 Huxley estimated that the practical results of Pasteur's discoveries had yielded France a return in excess of the war indemnity wrested from her a decade before—one billion francs. It is safe to assert that at present they represent to the world not less than that sum annually. And how shall an estimate be made of the relief of suffering and the preservation of life?

In 1894 Pasteur's former pupil, Yersin, isolated the bacillus of the bubonic plague, and had the pleasure of exhibiting it to his old master. "There is still much to do!" said Pasteur with a sigh. His health continued to fail steadily till September 28, 1895, when a final hemorrhage quenched forever the most brilliant mind ever bestowed upon a member of the human race.

Pasteur died a poor man, although, had he so chosen, he might have aggrandized himself beyond the dreams of avarice. But, considering that his ideas were heaven-sent, he bestowed them freely upon the whole world.

I can not find more suitable words with which to close this paper than those addressed by Pasteur to the students of the University of Edinburgh in 1884 upon the occasion of his visit there for the purpose of receiving the degree of doctor of laws from that ancient foundation. "Young gentlemen, work perseveringly. Work can be made into a pleasure, and *alone* is profitable to a man, to his country, to the world. Whatever career you may embrace, look up to an exalted goal. Worship great men and great things."

CONCEALING COLORATION[1]

By ABBOTT H. THAYER

MONADNOCK, N. H.

AT the last meeting of the American Ornithologists' Union, in Washington, some forty naturalists looked in broad daylight straight at a small stuffed deer that wore from its dorsal line down its sides two white stripes in imitation of those of certain African antelopes. These stripes were in every respect such as Theodore Roosevelt says have no *concealing* virtue of any kind whatsoever.[2] Yet they so completely concealed this deer in an almost clean-shorn public park that although for each of the forty spectators I pointed straight at the deer only ten yards away, not one of them detected it. The animal was placed just above the eye-level of the spectator, exactly as African antelopes would be above that of the creeping lions or leopards. And, exactly as would commonly be the case with the antelopes, the white stripes absolutely counterfeited the glimpses of the sky-background seen through the thin half leafless bush that intervened. When the white stripes were removed the spectators exclaimed at how clearly one

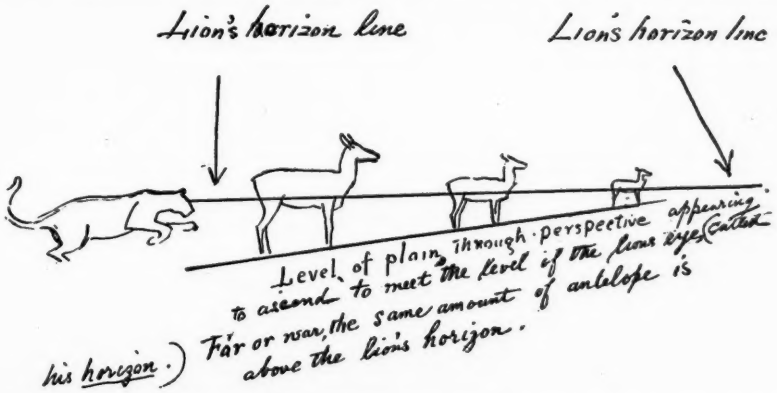
[1] These wholly unretouched illustrations absolutely demonstrate the wonderful concealing effect of the white patterns that Roosevelt and others say have no concealing effect whatsoever. These play, as Roosevelt truly asserts, little or no part when the wearer is out on the safe open plain, but seem designed for making him the very worst of targets when he tries to dodge the spring of an ambushed lion or leopard, especially at night, just as the night hawk's colors, dark and conspicuous to terrestrial eyes through all his safe aerial hunting, prove to be an unmistakable picture of his background when at last he squats on the bare rock in danger from predatory birds and mammals. No one can study these oryx head pictures without perceiving that, against the ground, the brown (of course countershaded) head is hard to distinguish, while the black-and-white one is very conspicuous. On the other hand, when the same two heads are *looked at from below, i. e.,* against the sky, it is the brown one that *shows,* and the brilliant black-and-white one that is now hard to detect. It is of this black-and-white oryx head that Roosevelt writes: "A curious instance of the lengths to which some protective-coloration theorists go is afforded by the fact that they actually treat these bold markings as obliterative or protective." Colonel Roosevelt, like the rest of the world, seems never to have thought to find out how these patterns look from a *lower level,* such as lions and leopards necessarily see from, they being under three feet tall, while the oryx and zebra are nearer five. This great oversight invalidates almost all that has ever been written on this subject.

[2] "African Game Trails," Appendix E.

could now see the deer, and all agreed that it was these white stripes that had fooled them. Dr. C. Hart Merriam said it was a most conclusive demonstration (though he still believed that such marks exist *also* for purposes of display, under other conditions).

The way this deer demonstration brings to instant ridicule the extraordinarily positive statements of Theodore Roosevelt must set the reader wondering about the value of the remainder of his attack. The simple fact is that Roosevelt, like most of the rest of the world, is totally ignorant of a great optical principle which has lain right under people's noses, and to which I have at last called attention, and which can not possibly remain ignored. All the various objections and doubts about our book, including this extraordinary tirade of Roosevelt's, have been possible *only* because of people's not seeing this principle.

The principle[3] is, basally, merely this: that if you lie on the floor you will have not the *floor* but the *ceiling* to look at, while if you were fastened to the ceiling you would see not the *ceiling* but the *floor*. All over this planet, and all over every other planet that receives light-vibrations and possesses detached objects of any sort, either on or above its surface, this law rules the aspect of every object in its appearance from the view-point of each other object. All such detached objects are for-


Lion's horizon line
Lion's horizon line
Level of plain through perspective appearing to ascend to meet the level of the lion's eyes (called his horizon.)
Far or near, the same amount of antelope is above the lion's horizon.

This diagram shows that Roosevelt is again exactly wrong when he says that to the lower-leveled eye of a wolf or cougar, a prongbuck's white rump shows *now against the sky and now below it, according to this enemy's distance.* If the antelope's rump is above the cougar's eye the same proportion of it will show against the cougar's sky at one distance as at another.

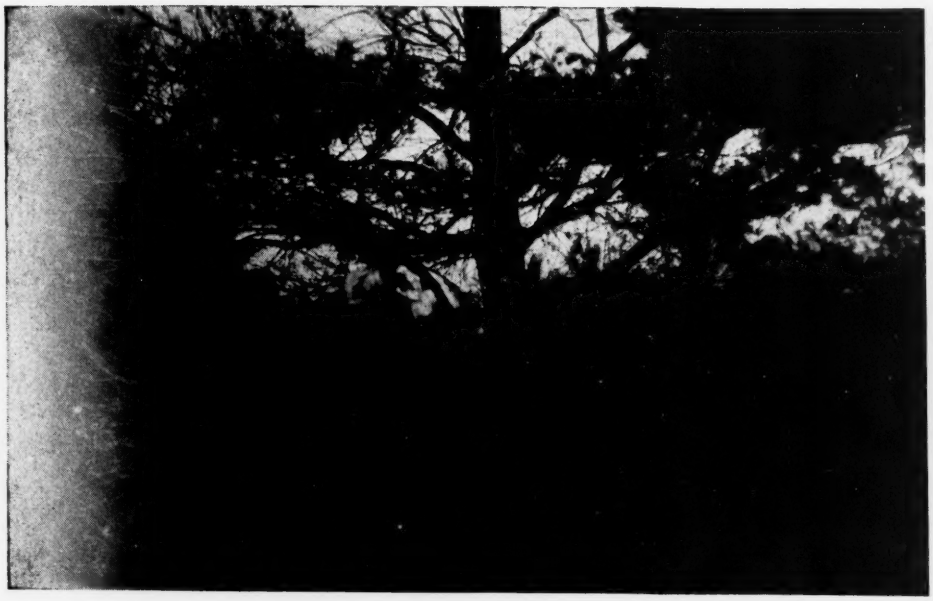
[3] Erasmus Darwin perceived this principle, but got confused in carrying it out—trying to make it explain the juxtaposition of brown backs and white bellies; the white of the bellies being, he thought, nature's attempt to match the white of the sky, for eyes beneath. Of course this *under* white can not do that, being always in shadow, and therefore practically dark brown—utterly too dark to match the over-head sky. On the other hand, white patterns on animals' *upper* slopes obey in every respect the law he foresaw, and operate upon the sight of such beholders as look from a lower level, except, of course, when the wearer is *directly over* them.

ever between the overhead light which is their *ceiling,* and the underfoot earth which is their *floor.* The higher you mount from the earth, and consequently the nearer you get to the outside of this zone of detached objects, the more do all things that you have to look at *come between you and the brown earth*—and the more these things resemble the earth in color the less you notice them. Contrariwise (let the world for the first time notice this *Contrariwise,* which would have saved Roosevelt and others so much erroneous writing), contrariwise, the nearer you get to the *bottom* of this layer of inhabitants of the atmosphere, *i. e.,* close to the earth's surface, the more you have *only* things *above* you to look at; and the more *these* things are *bright* like the sky the *less* you see them, and the darker they are the more you see them. This means that the nearer to earth's surface an animal lives, the larger will be the proportion of neighbors he detects by seeing them dark against the sky. Only such neighbors as are no taller than he will escape coming between him and his sky.

After years of trying to bring home to naturalists this great fact, which wholly suffices to account for white top-patterns in general, I know to my sorrow that nothing short of seizing them all and binding them to the ground, so that their eyes will be as low as a mouse's, will ever cause the truth to spring into vital existence for them! I have demonstrated to many audiences on both sides of the Atlantic where scarcely one man would consent actually to go down on the turf and let this immense fact rush upon his consciousness.

Everywhere, in every situation, it is the rule that animals are colored *like the background that most concerns their feeding and escaping attack.* Sea-birds, in general, are either all ocean- and sky-colored, or this with the addition of the color of the rocks they breed and roost on. Animals living between bare snow and sky are white. (I have shown by ocular demonstration the wonderful aid that this white background-matching gets from the small black marks commonly worn by these white species.) Sand-dwellers, on land or in the sea, are sand-colored. One can find pictured on a locust the peculiarities of the special type of ground he lives on, be it rock, or sand, or meadow. *Everywhere,* in every case where the animal's background is most unvarying, as in the above-cited instances, the animal's colors are at least *amply accounted for* by their matching of this background.

Now why is it that even after people *intellectually* perceive that a terrestrial mouse or lizard sees almost all sizable neighbors *against* the light, and detects them *least* when they look lightest—why is it that these people go on failing to undersand that white upper slopes on all species which need to avoid the sight of these mice and lizards are just as necessary to their wearers as is the *brownness* of the mouse or lizard, whose enemy looks at him from *above downward* and consequently sees



An imitation oryx head, looked *up* at, simulating branches against the sky—as at a reedy drinking-place it would simulate reeds.

The same oryx head and also a brown (counter-shaded) one, the former inconspicuous, the latter less so.

him *against the ground?* In each case, the animal's colors comprise all the background's typical color-notes. Under foliage, the lizard, looking *up,* sees things against a tapestry of dark twigs and the shadow-side of leaves—the whole mass *sharply patterned by bright glimpses through it of the sky above it all.* And this *ensemble* is precisely what is worn by dusky-coated white-top-striped animals that come between the lizard and this background.

What bewitchment of the student's mind thus holds him from discovering the truth that there is evidently just one universal need of *minimized visibility from the point of view which most concerns the creature looked at,* and that nature inevitably grants this minimized visibility to all creatures that can use it?

Here is the explanation of the misunderstanding. The basic use of men's brains is one which they share with the lower animals. Like all these animals, man lives, primarily, not by speculative reason, but by what for convenience we may call *mere sensation-memory.* The aborigines differ from white hunters by their still greater propensity to hunt always where they have once killed. And a horse that has once been scared by a factory whistle going off too near him on the road always afterward shows alarm when he passes that factory. Man is, we feel sure, one story higher than the other animals, and on top of what he shares with them adds a more or less vigorous layer of "reason." But let anything make the least bit of a *run* on this reason-bank, and he is bankrupt indeed, and falls back on his *sensation-memory.*

Let us examine a few of the limitations governing the vast accumulation of man's sense records. Here, for instance, is a thing seldom thought of: Man is, mainly, a *looker-down*—perhaps as much so as a cow. He tills the soil, he hunts, he fishes—largely or wholly *looking downward* in all these occupations. And the men of towns look still more predominantly *down* on desks, tables, tool-benches, etc. This habitual down-looking of men is well attested just now in New England by the difficulty the hunters for the brown-tail moth nests have in accustoming their eyes to day-long searching of the tree-tops. A few weeks of this looking *up* strains their eyes. Another proof of all this is that men say *white* is the color that shows by night. This is the idea of a race that mainly looks *downward.* A mouse, on the contrary, because almost everything comes between him and the sky, would consider *black* the color that showed best in the night. Now when some one asks us to form a clear idea of the mouse's (and the creeping lion's and leopard's) view of the animal kingdom, our thinking-power balks, and we fall back on our *sensation-memory,* which vouchsafes us, generally, not a single instance of view from this low level, while it deluges us with memories of the bird's-eye view that we habitually get of these same species. If we are forced for a moment into the realm of *thought,* in the next

The same effect as in the preceding.

The same two heads seen against sky and branches.

moment this relatively scant faculty is fatigued, and we fall back into the hands of the old animal instinct, *sensation-memory,* which we share with the horse and woodchuck, and we proceed to rattle off the list of the hundreds of times we have seen one of these white patterns, the skunk's or deer's (bright against the *ground* as man's *height* makes to be the case). But these white tops are white evidently because *concealment* from a *lower level,* for one purpose or another, is the thing most important to the animals so patterned.

Roosevelt carried into Africa the regulation *down-looker's* misconception of the subject. And nowhere on all his pages (or in fact on any other man's pages) is to be found the faintest perception that all these white patterns on zebras and antelopes were playing a *diametrically opposite* part to the eyes of the creeping enemies of these plains-haunting animals.

Colonel Roosevelt, with the best intentions, was fated to put himself on record in the most unfortunate of attacks on our book—an attack which forces us, if we answer it at all, to expose its extraordinary weaknesses. It is the nearest to one hundred per cent. of error that I have ever read, on any subject that I understood.

First, he shows fatal ignorance of the laws of optics on which the whole thing rests, and consequently absolutely misconceives what concealing-coloration *is* or *could be.* Secondly, he does not see the joke against all who try to prove that nothing has *escaped* their sight by telling what they *saw.* He would be too sagacious to apply such reasoning to practical affiairs—why does he take science less seriously? When I announce to the world the discovery of an almost universal concealing-power, *under certain conditions,* in animals' costumes, what has it to do with the case to tell of the animals one *has seen?* Let us apply Roosevelt's method to some practical case. If the police announce the discovery in the garret of some respected citizen of a complete counterfeiting apparatus, with every sign of daily use, what does it avail to testify that you have seen the citizen hundreds of times *not* counterfeiting? The discovery of the evidence compels an investigation. If the owner of a game preserve discovers in the cellar of some neighbor a supply of freshly used game traps, what does it avail that this neighbor is daily seen *not* trapping? Again only an investigation will do. What I have discovered is that all these patterns of an animal's costume *are* potential counterfeiters, of the most perfect kind, ready for action (action in some cases almost constant, in others only at rare, but vital, moments) —each one a most exquisite reproduction of *some* background typical of the wearer's habitat. An *artist* is of course the judge of such copies; and it is therefore as an expert that I pronounce on them.

No amount of reiterating that you have seen the poacher *not* poaching, or the bank-note counterfeiter not counterfeiting, or this newly

The same two heads against the sky; the black-and-white one hard to distinguish, though (as in most of these pictures) wholly uneclipsed, the brown one, though masked by many branches, very conspicuous.

The same two heads, but looked *down* at, as man commonly sees animals of lower stature than his own. The black-and-white one now *conspicuous*, the brown (of course counter-shaded) one hard to see.

discovered animals'-costume-scenery-counterfeiter *not counterfeiting* scenery, is any step at all toward finding out whether they all three do at certain times perform their tricks. Forty years of daily meeting the poacher at the post office does not strengthen his credit. And forty years of Roosevelt's seeing zebras *not* hidden by their costume, and failing to guess what the animal's stripes are for, are just as little to the point.

This *effacing machinery* is not the only highly specialized mechanism that animals *carry always with them* merely to have ready for occasional need. It is just the same with many of their other members and adaptations. The tiger's tremendous claws, if we estimate that he kills only once in two days, and that it takes perhaps four seconds for him to do it, are in operation only a 44,700-th of his life. Would Colonel Roosevelt for want of seeing them at their work decide that it was only a *theory* that they are *for* pulling down game? (I, by the way, do not even stop at the evidence that animals' costumes *are for* concealment. I point to the actual concealment in full operation.) The tiger's whole massive steely build serves him scarcely more constantly than do his claws. It, with the claws, does the pulling-down, and adds the bearing-away. The rattlesnake has a heavy rear body, growing slender and agile toward the head end, evidently in order that his terrible poison-apparatus may have a strong base to spring from. All this mechanism serves him only for occasional *instants*—days, weeks or months apart. Yet, there he always is, a heavy slow snake good only for lying in wait and for these rare murderous lunges, and totally incapable of the arboreal feats and racing of the black-snake's life. Would Roosevelt, because he so often sees rattlers *not biting,* hoot at the idea that this snake's fangs and build are made *for* biting? The generative organs of every monogamous species that breeds only once a year are carried through life for a few moments' function once a year—and so on and so forth. With costumes it is just as with all other adaptations. They may, according to their wearer's habits, play in his life a long part or a short one.

The particular herds and individuals of plains game that stood out so visible to Colonel Roosevelt were commonly those that happened to have the light behind them; and wherever any form of tree, shrub or very tall grass *constituted an element* of the scene, there were sure to be other herds and individuals in directions in which the illumination favored their counter-shading, wholly invisible amidst the haze of scrub and grass. A spectator in such a scene is surrounded with vast reaches of all-engulfing distance into which the haze of interposed scrub growth merges on every side. In these spaces a counter-shaded animal, when the direction of the daylight favors the working of his counter-shading, is already wonderfully matched to the scrub's color, and the

further off he is the more of this scrub actually comes between him and the spectator. There is therefore obviously *some* distance at which he is wholly *covered* by the scrub. Now from the very nose of the beholder all the way to the point where the animal is actually hidden by accumulated twiggery there is a scale of *diminishing visibility,* and, while the light favors the animal's background-matching, he becomes utterly indistinguishable from the scrub and grass *long before* he is at the point of actual eclipse. Yet Roosevelt is able to say: "There is never any difficulty in seeing them"! Compare Stewart Edward White's description of the evanescence of deer in similar situations,[4] written before he ever heard of concealing-coloration.

It is when the light gets *behind* an animal that its main power to upset concealing coloration comes into play. Except in the middle of the day, there is always one direction which is *toward* the light, and looked at in this direction the sheltering ambiguities of these thin coverts have to give up many of their secrets. An hour earlier the antelope's imitation twig-haze passed all right, but now that the sun is low and streams through the whole gauzy growth, behold, the opaque antelope becomes a black silhouette on a light gray ground. *He* is not really a gauzy growth!

It is hardly worth while to say that all these laws of light and its relation to vegetation are practically identical the world over. Though I have been through most of Europe, from Norway and England to Italy and Sardinia, and through most of eastern North America, from Quebec to Florida, and in many of the Lesser Antilles and Trinidad (finding everywhere, what I knew before I went, that the laws of illumination of animals and vegetation are the same over the whole planet), I have *not* been in Africa. But—and this is more to the point—my critics have evidently not been in the land of the inexorable optics which govern this entire matter.

One of Roosevelt's most fundamental errors is his complete gap of perception about the effect of *motion* on concealing-coloration. In our book's introduction I say: "Thus at these crucial moments in the lives of animals, when they are on the verge of catching or being caught, sight is commonly the indispensable sense. *It is for these moments that their coloration is best adapted, and, when looked at from the point of view of enemy or prey, as the case may be, proves to be obliterative.*" Had our critics studied this sentence, it would have saved them much misapprehension of what the book is about. But here let it suffice to remind them that the tennis-player's need of bright, clean, white balls, to be seen against the green turf, entirely refutes their ideas. The tennis-player calls for clean balls when the grass-stained ones are beginning to spoil his play; and well might a hawk, if his call would avail,

[4] "The Mountains," Chapter X., On Seeing Deer.

demand a "clean chipmunk"—*i. e.*, an *un*-counter-shaded and *un*-dead-leaf-colored one—when the little beast dodges him. Note, too, that a grass-stained ball against the grass is, at its worst, far more conspicuous than an average chipmunk against the leaves, because the ball *turns over,* and therefore could not be counter-shaded. (Note also that predators in general are believed to *miss* far oftener than they succeed.)

Many familiar experiences prove this fact, that one's power to catch or hit a moving object depends on the *distinctness* with which one sees it. The more brilliantly a dodging object shows against the background, the more promptly can the brain of the pursuer command the corresponding movement. Those who have tried to catch butterflies, house-flies or mosquitoes, on the wing, or shoot a flying bird, either know this by heart or will realize it the moment they try it again. When a dark fly passes a dark space, to make sure of him you wait till he gets against a *light* space, and a shooter does the same with a bird. Throughout all nature animals' coloration proves to be such as minimizes, in the most wonderful way, to the eyes of their pursuers, their visibility *when in motion.* And in missing this fact Colonel Roosevelt has missed a vast part of the whole wonderful subject. So true is it that, as he says, motion almost ensures *detection,* that it is no wonder we find concealing-coloration by far most constantly needed and at work—making the wearer *as hard as possible to* CATCH—where there is *pursuit and flight.* This matter would come home clearly to Colonel Roosevelt if he would try to hit a concealingly counter-shaded moving target against a background that it matched, and see what kind of a score he could make compared to what he could do with an un-countershaded one.

As soon as the public have been shown the astounding concealing-power of those African animals' reed-and-sky counterfeits, such as the zebra's and oryx's—which make it as hard as possible, *by night as well as by day,* for the springing feline to distinguish between starting zebra and jostled reeds—they will begin to see how complete has been their misconception of this matter. And the moment they see a demonstration of the magical working of facsimiles of these animals amidst reeds and branches, out-of-doors, they will see at a glance *that it would be just so anywhere in the world.* Colonel Roosevelt has confounded *detection* with *catching.* There is a vast difference. Every animal that has lived a year or two has been *detected*—how many thousand times—by other animals that would gladly have caught him; yet there he still is! Detection means, in some cases, much; but in far more case it means little. As Roosevelt evidently thought about the plains game, *out in the open* detection is nothing to them. He is also right when he says that these animals, zebras for instance, are sure to be observed by the *ambushed lion* as they nervously troop down to drink. The reader shall see how wonderfully their case bears out the hypothesis that all

available adaptations of an animal's body *will be found ranged against his life-and-death danger.*

Out in the open, the zebra's watchful eye and ear, backed by his agility, ensure his safety. But if he pass too near any cover as ample as the lion *must have* for his operations, his stripes begin to be a safeguard, because *cover enough to conceal the lion means reeds or branches silhouetted across the lion's view of the zebra.* The zebra is inevitably against the crouching feline's sky, and his own sky-and-reed counterfeit begins to have the advantage of confusion with the real vegetation through which the lion is *condemned* to look. A chain is no stronger than its weakest link. What is, obviously, the weakest link in the zebra's life chain? It is when he must risk *the lion's ambush and drink.* All available powers of getting through this tightest place in his life are sure to be found in operation. This *need to drink* is as much the crux of the zebra's life as the need to be able to swim would be the crux of a foot-passenger's journey from New York to California, if there were neither boats nor bridges. There will arrive in California no foot-passengers that can not swim, *because there is the Mississippi.* And there will survive no race of zebras that were not the watchfulest, the agilest and the hardest to see when they *had* to go through this greatest danger of their lives. It is their Mississippi. When a zebra comes to a drinking-place, the faintest sound that could mean an ambushed lion *must not pass undetected by him,* and he starts away from the faintest rustle. The crouching lion sees him come into the reeds—sees him all the time—and if the zebra comes within range, *springs upon him,* but even in his first spring has inevitable difficulty in distinguishing the zebra's outlines because of the absolute similarity of the zebra's imitation of reeds and sky to the real ones. The zebra's uneasiness keeps *both the real and the counterfeit in motion together.* Very often, doubtless, as the best naturalists seem to agree, the zebra's automatic *start* comes in time to save him, and the lion's instantaneous now-or-never *second spring,* such as probably all felines make, must be guided by a lightning-swift perception *which* of the violently agitated sky- and reed-stripes are the zebra and which are *not!* Any one who saw my deer at Washington will understand this (and better still will any one who will come to Monadnock and see the wonders of my artificial zebra and oryx). Plainly, then, since the zebra *must* at this necessary moment be terribly near the lion, his race could not have continued except by having every counter-balancing advantage; and it is demonstrably *here* that the full magic of his coloration comes into play. These sky-counterfeits are as plainly addressed to the lion's sight, and most of all at the night drinking-place, as the thickness of a grizzly's frontal bone is addressed to the teeth of his enemies.

Colonel Roosevelt has done himself a wrong by not studying our

plates of counter-shaded "vanished" models. He does not seem to take in at all the marvelous power of this counter-shading, which can actually *efface* the thing on which it is painted. And he has an idea that it chiefly affects the lower part of an object—as if it were merely a juxtaposition of dark top to white bottom, instead of a continuous gradation over the animal's entire surface. He says: "But as a matter of fact, the great majority of these mammals, when they seek to escape observation, crouch on the ground, and in that posture the light belly escapes observation, and the animal's color pattern loses very much of, and sometimes all of, the 'full obliterative shading of surface colors' of which Mr. Thayer speaks." Let Colonel Roosevelt cover the lower half of one of our "vanished" models, in our book, and see if this cause the *upper* half to appear! Or let him cover the lower half of the *visible* monochrome model, and see if this cause the upper half to *dis*appear.

Two more particularly flagrant errors of Roosevelt's must be mentioned. First, his speaking as if an animal's *not trying to hide* disproved his being concealingly-colored. He will in time discover that in a vast majority of instances, the very reverse is the case: that the more an animal *doesn't* hide, the more nature has to help him by coloring, precisely as in the case of the zebra at the drinking-place, or the humming-bird with his head stuck into a flower, or the flamingo at dawn with his head in the mud. Second, his much-insisted-on idea that if *one* coloration is a concealer, a different one on an animal of the same general habits isn't. He might just as well apply this objection to the mixed herds of diverse-shaped African game, of which so many species have closely resemblant habits, saying, for instance: "If the zebra is built right for this life, then it is a physical impossibility that the oryx is." Or to the innumerable forest plants, each with its own shape, but with, to the casual eye, identical circumstances. Or, concerning such a company of birds as feed together on the marshes, he should say: "These curlews, plover, and sandpipers live together and eat the same things; but if the curlew's bill is the right shape for his life, the very differently shaped bills of the other species are accidents and not adaptations." This is an old, obsolete method in natural history, henceforth to be succeeded by pure experimentalism. And I am presenting simply *the experimentally established facts* of these marvelous background-matchings. Amid sunlit snow and blue shadows the blue jay *is* exquisitely 'effaced' by its most perfect matching of each color-note. Likewise the peacock up in a tree, or the wood duck among sunlit water-plants, etc.[5] Each of these *facts is here to stay,* no matter where it leads us.

[5] One of the many surprises in store for Roosevelt is the potently obliterative character of the summer dress of the male bobolink, *when seen from the hawk's viewpoint.*

Our book[6] was written only after all its facts were verified. It contains essentially nothing *but* facts, and might have been called an expert's presentation of examples of consummate resemblances between animals' costumes and certain of their backgrounds. It has greatly surprised us that so many people have so slightly noticed the *facts revealed* as to take them for illustrations of a supposed "theory." The *facts, themselves,* are what we present.

From now on I shall be delighted to show to all comers to Monadnock the perfect background-counterfeiting powers of all sorts of gorgeous birds and butterflies. I have already prepared good facsimiles of a zebra and the head of an oryx, to show the truly wonderful way in which when looked at from a creeping lion's or leopard's eye-level these animals pass for mere sky-vistas through the reeds or branches. My Washington deer was merely a crude beginning of the exhibitions that I can already give of this type of concealing-costume.

Any child who has access to a wide, open field away from lights can prove for himself that *white does not show against a starlit night sky.* And it is only fair to point out that any one so ignorant of the simplest laws of optics as to share the popular notion that it *does,* is not competent to testify in this matter. Let the experimenter hold up between his eye and a clear, moonless night sky, a white card so inclined as to permit him to see its upper side.[7] Even in a wide, open field he can at most make it come *as* bright as the sky beyond it, and consequently *vanish;* but it can not of course get *brighter* than the sky. How could it, since it owes all its light to this very sky! Yet Roosevelt says: "At night, in the darkness, . . . the white rump-mark of the antelope is almost always the first thing about them that is seen, . . . and at night it does not fade into the sky, even if the animal is on the sky-line."

Many persons who hear of the vanishing-power I show in the brilliant bird-skins and butterflies and these white-topped animals suggest that in the animals' homes all might be different. I need only answer that when they see the vast range and astounding precision of what I show, this fear will vanish. The evidence is literally overwhelming. It is in every case only against a background notably like that of the animal's home that he will vanish.

[6] "Concealing Coloration in the Animal Kingdom."

[7] Moonlight, of course, or the uneven illumination from a cloudy sky, can make white show momentarily brighter than the sky; but nature has to deal in *averages,* and these very irregularities of illumination cause the prongbuck's white just as often to look too dark as too light.

Contradicting what he says of the skunk's white, Colonel Roosevelt says: "After nightfall the zebra's stripes would be entirely invisible." Here again he is completely wrong, as if he had never hunted by night. These stripes are invisible at night *until* the enemy is near enough to endanger the zebra. Looked at as near as this, all colors *except* white, show strongly against a starlit sky.

Like John Burroughs in his *Atlantic Monthly* paper called "Gay Plumes and Dull," Colonel Roosevelt does not even take pains enough with his data. Burroughs said: "Why does only one of our four weasels turn white in winter?" The answer is that *all* of the four turn white in winter! Roosevelt says: "Bears . . . have no white on them." The fact is that seven species, without counting the two all-white kinds, wear more or less white, especially in breast-crescents, collars, and fore-shoulder stripes.

About war-paints and appendages, too, I tell only optical, invincible facts. On this subject I shall soon have more to say.

The possibility of wonderful demonstrations of the effacing-power even of stuffed skins of gorgeous or powerfully marked species such as a peacock, or an oryx or zebra, is unfolding itself to me at a rate that almost takes my breath away, and which can not fail to astonish all who witness my experiments.

Not yet understanding that this matter is unequivocally the artist's business, Colonel Roosevelt, like some of our other reviewers, proposes a "scientific" tribunal for our book. *Science* means simply *knowing.* What does science teach any scientific man more imperatively than that he must employ specialists in every direction? Does astronomy fit a man to practise medicine? Yet the astronomer and the doctor are both men of science. Do naturalists imagine that the arts can stand as they do, illuminating beacons through the ages, without having adamantine, crystal truth at their core? The laws of color-correlation are of course the very axis of the art of coloring, and any intellectual painter inevitably *is* the scientist of all that is knowable in this matter. While all painters perceive spontaneously that shadows on the snow in a sunny open field have exactly the color of the aggregate overhead sky, very few persons who are not artists can discover that they are more than "bluish." As our book's introduction explains, a colorless mirror laid in such a snow-shadow and facing upward reflects of course the overhead sky, and this reflection proves absolutely to match the snow-shadow. This knowledge of the actual color of things, and especially *of transitory aspects,* rests, then, wholly with painters; and, if *scio* means *I know,* it is *science.*

My critics say it is my *theory* that this or that bird's patterns pass for the background; yet every time I show them this bird against such a background, they either fail or nearly fail to detect it, and invariably admit that it was its patterns' resemblance to background-details that fooled them. Is it my *theory* that they are thus deceived?

Will not my critics wisely adjourn for the present the question of the validity of any *deductions* I may have made, and contemplate instead the array of actual *facts?* Whenever naturalists will take the trouble to lie down on the ground beside a stuffed flamingo, or a live

one in a zoo, with horizontal sunlight bathing it, they will *see* that it looks wonderfully like a pink cloud (which is, strange to say, just what Roosevelt remarks about a flying flock of the African species), and all *discussion* as to whether this is so or not will be at an end. In connection with a long chain of similar phenomena, hitherto unknown, is this *fact* worthy only of derision? If inhabitants of the world's *floor* prove to see the more aerial species against the sky, the flamingo's aquatic enemies, dwelling *below* this floor, see denizens of the upper air *always* against the sky. The flamingo question, then, has come down to why he is colored for dawn and sunset sky more or less at the expense of his all-day matching. The answer would seem to be connected with his nocturnal habits. According to Audubon the red flamingo is nocturnal (as, apparently, all the other red and rosy waders are); and in that case his feeding wouldn't extend further into daytime than merely, at both ends of the night, to overlap into the rose and salmon light of dawn and evening. His feeding is especially unfavorable to his keeping watch against enemies, since he buries his face in the mud and muddy water in his search for the worms and other animals he lives on; and we find his coloration fitting this emergency.

This matter of sky-matching has come very clear in my demonstration with the oryx head, reproduced herein, which shows the inevitable effect of all the other branch- and sky-patterns, such as abound on birds, beasts and butterflies that are looked *up* at. I have been studying for years to find out the *exact* scene that each costume best represents; and I now beg my readers to come to Monadnock and let me show them the results.

EXPANSION OF THE USEFULNESS OF NATURAL HISTORY MUSEUMS

By Professor THOMAS H. MONTGOMERY, Jr.

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LIFE consists, to a large degree, in adjustments and responses, with institutions as well as with individuals, and the new conditions that these create must be faced in their turn. With every active growth there is branching out and so arise innumerable interlacings and entanglements of activities, one overlapping and interweaving with the next. The whole history of thought shows how subjects that once were to great extent isolated have spread out and crossed, until they compose a tangled web of endeavor, and consequently we can no longer define our sciences sharply, for each of them mingles with others on all sides. Indeed the borderlands of any science, the points where it joins with another, now make up the most interesting and promising fields of research. Thus biology at one angle passes over into medicine, at another into psychology, at another into sociology, one little corner threatens to join with mathematics, and at nearly every turn it meets with physics and chemistry. He would be a rash man who would try to-day to present a rigid classification of the sciences, they being in such a flux and flow of change; indeed they are coming more and more to constitute a unit.

But each worker has to select a particular part of this web for his study, for the reason that no man can undertake the whole; it once was that a strong mind could grasp the entire web, like as the mother spider controls all lines of her snare, but now the web is so great and complex that we single workers are like spiderlings upon it, each looking for his own particular little gnat. We single laborers associate ourselves together according to our tastes, so as to favor interchange of thoughts, thus forming societies, academies and the various other kinds of institutions, and the time has come when these different institutions should cooperate and partition out the work to be done by each, so that there may be as little waste and as little duplication as possible. For while there may be as great difficulty in characterizing institutions as in defining sciences, nevertheless mutual cooperation and division of labor have come to be a necessity.

Probably the oldest European association of naturalists was the academy, a grouping of followers around a gifted thinker. In the days of Greece such academies usually had no habitation, but the disciples

followed and heard their master in the open air. In such an academy the teacher had his own doctrines most at heart, not those of others, consequently did not try to accumulate a library. Libraries arose in the orient earlier than in Europe, partly from the reverence of the eastern nations, particularly the Mohammedans, for the written word, partly from the greater age of eastern civilization; through Europe libraries arose in kingly palaces and in priestly monasteries, and these were, before the days of the printing press, the centers of book making. The foundation of distinct natural-history museums was considerably later than that of libraries for the reason that the voice of authority long took precedence over the concrete object; witness the long contention of bookly scholars over the number of legs of an insect, all disputing over various renditions of Aristotle, none condescending to catch a house fly and count its members. Alexander brought home great collections of living animals from the east, and founded therewith a zoological garden for this teacher of his, but we have few records of this collection; the beasts the Roman emperors secured were used mostly for combats in the circus, for these emperors had political and popular effects in mind and not the increase of knowledge.

The materials for the study of the natural sciences in medieval times were the libraries, museums growing up in Italy and England, and universities starting in Italy, Spain, England, France and Germany. These early universities were at first much of the type of Grecian academies, with didactic teaching; they arose from the desire of certain free spirits to gain knowledge of other kinds than that prescribed by the church. We can say that the museum was in most instances the mother of the empirical natural sciences, for it stood for the accumulation of objects of study rather than the accumulation of books. Men of inquiring mind grew up, inspired partly by curiosity, partly by superstition and belief in the black magic, who collected monstrosities and other strange specimens, without any definite idea to guide their choice; their preference was for fossils and crystals, salamanders and hedgehogs, and in general the most heterogeneous objects as one may learn from " Hudibras " or from the plates in Johnston's " Natural History." The wish was for the unusual, and specimens from foreign lands inspired much more interest than those of the native fauna and flora. The chief growth of these museums dated from the times of colonial expansion, when the ships of the Dutch and Spaniards and English brought home collections from the new and old Indies. The governments then lent their help to the museums, as an exploitation of the products of their new possessions, and the great collections of London, Paris and Amsterdam jumped in their growth and importance and have justly become objects of national pride.

The universities came to join with the museums in many cities, but

have for the most part remained separate from the older of them. Perhaps the chief reason why the universities and museums have kept apart is the character of their work; natural science in a museum consists largely in accumulation of collections and in descriptive research, in the university in experimental science. This makes up the essential difference between the curator, on the one side, and the laboratory worker on the other; or, in other words, between the classifier and the experimenter. And it is curious to note that laboratories arose first quite apart from both museum and university, in the private houses of men of analytic mind; one needs only recall the names of Roger Bacon, Vesalius, Galileo, Harvey and, in modern times, Darwin. And those who were interested in comparative anatomy and physiology were at the beginning for the most part private physicians. As this work gained in importance they moved naturally to those institutions that offered the greater facilities for that kind of pursuit, consequently to the universities.

This has been the merest historical sketch of the connection of museums with other learned associations, while the subject is one of sufficient interest to fill a volume and then be far from exhausted. But it will have to suffice for our present purpose.

Now let us see the present ramifications of our institutions of natural history, and limit ourselves to the subjects of biology and geology. Of these there are, in the first place, the general academies, which may be characterized as being broad in subject, and open to all who are interested, to layman as well as to investigator. The latter quality is a particularly valuable possession, by virtue of which became associated in common interests many people who would find themselves alien in a more specialized association; for the specialist's research is largely dependent, at least in America, upon the gifts of amateurs, and all specialists are recruited from the ranks of amateurs. Probably the amateurs who are drawn to an academy by their natural tastes make better members than those who have chosen their calling after deliberation. The academies publish "proceedings" which include the most diverse subjects. Then there are museums, frequently associated with such academies, less usually with universities. Their primary object is the conservation of collections, and they have the same relation to natural history specimens as libraries have to books. The greater of them are reference collections where one goes to find the original specimens of descriptions. Their curators are men whose writing is largely limited to the materials of such collections and to the theoretical ideas based on such material. For the most part these museums now separate their reference and exhibition collections, and devote much thought to the most suitable presentation of the latter, following Huxley's thought that an exhibition collection should not aim to show all its

specimens but rather to place on view particular groups of a direct teaching value. How far even the best collections do actually teach is, however, a matter of much dispute among museum directors. Some museums are trying the plan of frequently changing the exhibition collections, so as to offer more variety to the public. Thus the exhibition collections represent faunæ, factors of distribution and of evolution, phyletic series, habitats of animals, stratigraphic series, etc. For the gathering of collections of these two kinds museums, as far as they are able, send out regular collecting expeditions; and indeed our National Museum is, to a great extent, the result of natural explorations. Both academies and museums usually maintain public lecture courses—as now do almost all learned institutions.

The work that the museums are doing in biology is mainly taxonomic, the study of groups, and ecologic, that of life environments. Their teaching is accomplished by short lecture courses, natural history excursions, and by exhibition of collections illustrating particular subjects.

The remainder of the work in natural history is done mainly in other institutions. Mineralogy is the branch of geology studied chiefly in universities and various technical schools. Almost all the branches of biology, except taxonomy, are taught outside of museums. Morphology and physiology are followed mainly at universities and marine laboratories, the experimental study of evolution including inheritance at these and at special experimental stations—governmental and private, and the newer sides of biology, biochemistry, biophysics and comparative psychology are practically unrepresented at the museums. For experimental research as distinguished from taxonomic, in fact for the study of vital details of any kind, one goes to a laboratory rather than to a museum.

Thus, on the one hand, there is the natural-history museum. Its research presents the historical or phyletic standpoint, and tends to consider the entire adult organism without attempt at abstraction of particular qualities. There is the laboratory proper, at university or marine or fresh-water or experiment station, that digs into the inside of the animal with the microscope, that tries to trace its whole development, that attempts to reduce its processes to known physical and chemical factors. The two sets of institutions are, on the whole, sharply differentiated, their work is contrasted, one can not say *a priori* which has the greater importance, but in time we shall be able to decide which has brought the greatest treasures to human knowledge. Certain it is that the pioneer work of the taxonomist opened the way for the theory of descent, and that without such work the experimental student of evolution could hardly attack his subject. And high-class taxonomic work requires as rare judgment and intuition as is demanded in any other scientific pursuit.

Foremost among the institutions to-day stand the universities and the museums; all others are represented by men who have been trained in one of these two. Now what should be the attitude of them to each other, especially when they coexist, as they often do, in the same city? Mergence has been suggested, but it would appear, unwisely. For each has its honorable traditions and does not wish to surrender independence. Further, they represent such different types of work that they would accomplish much more by careful cooperation than by any blending, for coalition would produce a mongrel of less virility. The plan should be cooperation and division of labor in subjects in which they overlap, so as to avoid waste of energy, otherwise maintenance of present independence.

In these matters human knowledge and the methods of getting it are of prime importance, not the fair name of an institution; or we should state it better by saying men's labors give the name to the institution. For seen rightly a university or a museum is only a tool towards this end, and should not stand in the way of it. We often hear it said that a man is or should be an underling of a particular institution. This is radically wrong, at least provided the object of that institution is to increase knowledge and not merely to conserve it and pass it on. A university or a museum is a complex engine, but still a tool, and how it should be used should be decided by the men who know best its object, and those men are chiefly, but not wholly, the investigators —curators or professors. For a man of original ideas to subject himself to any crystallizing conditions of an institution is an anachronism and an anomaly. He serves his institution best who serves his subject most loyally. The subject is the goddess to be followed, the institution is only one of her shrines.

What we are all here for is to make the most of natural talents, and to cooperate for the good of our subjects. This can result only in benefit to the institution in whose walls we work. Applying this principle, let us see how museums may cooperate helpfully with certain other associations of naturalists.

For the most part museums fill an important place and represent activity that is not developed elsewhere. But there is some waste, and there are also opportunities that museums have not tried to grasp. For instance, little good is accomplished by public popular lectures, whether given by academy, university or museum; in my experience they appeal mostly to the mentally unoccupied, to those who lack resource in their evening hours. I would not say they are valueless, for sometimes their seed falls into proper ground, and also they eke out the salaries of poor curators and professors. But, on the whole, they are mistaken charity and so constitute a waste, unless great care is taken that there is not a plethora of them. Much attendance on lectures is

like much reading of books, a poor substitute for the activities of life. Again, universities often undertake work that might be much better left to museums. Thus if there is a museum conveniently near it seems to be a waste for a university to plan large taxonomic collections or even to give courses of taxonomic nature. For if a student wishes to learn species and their distinctions, he can gain this knowledge far better in the reference museum than in the laboratory; and to change a laboratory into a museum is to injure its proper use. Taxonomic collections and courses may well be omitted from universities, and students wishing these subjects should be directed to museums. A herbarium or a collection of shells is as much out of place in a laboratory as a bull in a china shop, for the university laboratory is for experimental work.

This idea may be pushed still further. When a museum has already large reference collections, not only there is no need of universities trying to duplicate these, but also the university should leave to museums the teaching of subjects for which such collections are the basis. This is the kind of teaching that would bring most results to the museums. Thus nature-study courses of all kinds could be best presented by museums, with their large local collections and their curators trained in knowledge of species and habitudes. Systematic courses in entomology might also be most profitably given in a museum; and these are growing in importance, now that insects are receiving so much attention by agriculturalists, and by physicians in their relation to disease. Practically all of our best entomologists, mammalogists, ornithologists and systematic botanists, whose work is of the greatest practical importance, have grown up in museums. But at the present time their training consists in becoming assistants in museums, helping in the arrangements of collections with no training whatsoever in the broader sides of the subject, and taking many years to learn what they might otherwise gain in a much shorter time, provided their work was directed from the start. A man told to label a certain collection will in time learn how to do so, but if he is to do more than merely determine species he must follow a plan of work. Such a course might be worked out in some such way as the following. The curator of entomology might each year direct a course in general systematic entomology or on injurious insects. The teaching need not be done by lectures, but with specified work on the object to be carried out by the student, assigned reading and practical examinations. Not much of the curator's time need be consumed, he would simply have to outline the work and to occasionally oversee it. The student would then begin with the advantage of the help of the judgment of a trained specialist. It stands to reason that such a course under a competent entomologist could be done better in most museums than in most universities. Such an initial

course might be followed by one upon some special group of insects, or by one upon insects affecting a particular industry. A student who had taken such courses could on their completion readily find a position in some other museum or in a governmental station; and surely this would prove a better method of training systematists than the present way of acting as an assistant in a museum, for the work would be definitely planned from the start. Similar courses might be offered in mammalogy, ornithology and piscology, and in geology and paleontology, for all these subjects require large collections. Forestry might also be included in part. Without doubt universities would be glad to cooperate in such work, by advising students to attend such courses, and by crediting the work towards academic degrees.

This would be a new expansion, but logically a part of the work of museums, more important than public exhibition collections and far more important than vicarious evening lectures; though these evening lectures might be rearranged so as to compose a part of the courses. How important the matter is may be seen in the fact that the U. S. National Bureau of Entomology employs some 300 men, and finds it has to train most of them for the work; they would most gladly have other institutions undertake this training. The universities are attempting to present such courses, but they are greatly handicapped by the lack of suitable collections and of systematic entomologists. A university department of biology has to give courses, and direct research work, in histology, anatomy, embryology, physiology, animal behavior, inheritance and other analytical subjects, all of laboratory nature that require apparatus and living material rather than collections; it is too much to require that they should also present the taxonomic subjects. We should not attempt in an inland university to maintain large salt-water aquaria, but go to a marine laboratory for the sea organisms; and unless there is much ground around a laboratory, we do not attempt experimental breeding in a large scale, but go to some experiment station. Equally when a subject requires large taxonomic collections we and our students should go to a museum for them, and not try to amass other collections.

Since this was written I have learned that the Chicago Academy of Sciences now presents teaching courses which receive credit from universities. This seems to me to be one of the most promising fields of expansion of the usefulness of a museum. It would bring about a serviceable cooperation with other institutions, and thereby result in economy of expenditure and effort.

The second enlargement of the museum's service is increased research. Certain museums have been most prominent in research, as the British Museum which has surpassed the universities of its land. But few others approach this museum in this respect. To my mind a

museum that consists mainly of collections, and of simple caretakers of these, has a speaking resemblance to a graveyard; dead specimens and gravestones betoken the past, and a mere conservator, like a sexton, has little to add to the future. It is as sad and melancholy a state as that of a university whose professors are nothing but teachers and committee men. There were magnificent collections in Pompeii, but so long as they remained buried beneath the soil they were of absolutely no use; they became of interest only when experts examined and interpreted them. I recall well a certain museum, founded out of piety, full of dead bones, where for years the only persons of any useful activity were the janitors and mechanicians; and it had an honorable board of directors too. Museums may become stagnant quite as well as other institutions. When the preparator and mounted rhinoceros are considered above the curator, and the exhibition collection above published research, then a museum is becoming senile. The strength of an institution lies wholly in its men. Past achievements are honorable possessions, but like an old family name entail the greater responsibility on the bearer. Any one who lives in the past will be treated like the past, and drop out from the race. For what museums do we call the great ones? Those with the staffs of prominent investigators, where there are many curators and all active in research. It is just the same with universities; international reputation is not based on buildings and number of students, but upon the number of original thinkers who publish. A dictionary is a museum of words, but it has no particular use until some one comes along and uses these words for a writing that people will read.

Very frequently a museum expends a sum for a single specimen or for a collecting expedition, sufficient to maintain several good men for a year. Often again it has a chance to secure an investigator, and hesitates because the expenditure would have to be drawn from some library or janitorial fund. Too often it is apt to consider the exhibition series to be its main purpose, and to regard men valuable only as arrangers of the exhibition. The saddest trait of all is self complacence, satisfaction in conditions as they are for this marks decay.

New timber must be planted, or any institution will soon lose its prestige. Worthy collections should be housed in suitable buildings, but the crown of the whole is the strength of the staff of curators. They come first in the judgment of the world as opposed to local opinion. When one names the great museums of Paris one forgets the specimens in the revered memory of Lamarck, Cuvier, Humboldt, the Saint-Hilaires and the Milne-Edwards. Such names constitute greatness, their writings have vivified the collections. America is too young to have many great names in natural history, but what reputation would our museums have without Horn, Say, Dana, Cope, the Agassiz's, Leidy, Baird and Gray?

The whole point is to try to live up to this record of honor, if possible to surpass it. That means to recognize capable men, to keep them by freeing their time as much as possible for their researches, and to call in capable outsiders. This is the principle of President Gilman, of Johns Hopkins University, "to discover and develop such men as have unusual ability." Each particular collection should be considered the basis of work for a particular gifted man, and not be its tender. Young naturalists starting out should be helped with fellowships and advice, substantially encouraged, not treated as preparators. Museums, you surely must agree, should make places for able men, just as universities are doing, recognizing it to be a part of their duty to help the subject by helping the men. It will be costly to do this, but not if a portion of the great funds given to getting collections be given to getting men. When this is done museums in general will be great teaching institutions, and cease to be cold storage centers. It may be questioned whether it is wise policy to say one must get buildings and collections first, then we can think of men. Would it not be wiser to attempt to add men and equipment simultaneously so that the new equipment may be used to best advantage? The cart must not be put before the horse, nor the fire before the food.

For the very reason that the American spirit is so eminently utilitarian and commercial, so highly uncivilized, the learned institutions should do all in their power to help those who are working for science. If they do not offer this help, who will? All institutions should combine in this endeavor to make it possible for inquiry after knowledge to increase. They should combine in every possible way to aid the man of original ideas, for he alone is the one who advances knowledge; he is the yeast in the bread. One of the most pitiful chances we can experience is to see a man full of hunger for a scientific career, driven to an uncongenial commercial calling for the lack of opportunity and timely aid; a naturalist shudders at the thought. Such cases are frequent, and human progress is by so much the loser. Is it not a duty of society to see that men do the work for which they are naturally fitted? Yet when we examine the matter seriously, we may well doubt whether our learned institutions fully recognize this need, and whether they are doing much to realize it. It is, nevertheless, probably the greatest good that they can carry out.

THE HISTORY AND VARIETIES OF HUMAN SPEECH[1]

By Dr. EDWARD SAPIR

THE CANADIAN GEOLOGICAL SURVEY

PERHAPS no single feature so markedly sets off man from the rest of the animal world as the gift of speech, which he alone possesses. No community of normal human beings, be their advance in culture ever so slight, has yet been found, or is ever likely to be found, who do not communicate among themselves by means of a complex system of sound symbols; in other words, who do not make use of a definitely organized spoken language. It is indeed one of the paradoxes of linguistic science that some of the most complexly organized languages are spoken by so-called primitive peoples, while, on the other hand, not a few languages of relatively simple structure are found among peoples of considerable advance in culture. Relatively to the modern inhabitants of England, to cite but one instance out of an indefinitely large number, the Eskimos must be considered as rather limited in cultural development. Yet there is just as little doubt that in complexity of form the Eskimo language goes far beyond English. I wish merely to indicate that, however much we may indulge in speaking of primitive man, of a primitive language in the true sense of the word we find nowhere a trace. It is true that many of the lower animals, for example birds, communicate by means of various cries, yet no one will seriously maintain that such cries are comparable to the conventional words of present-day human speech; at best they may be compared to some of our interjections, which, however, falling outside the regular morphologic and syntactic frame of speech, are least typical of the language of human beings. We can thus safely make the absolute statement that language is typical of all human communities of to-day, and of such previous times as we have historical knowledge of, and that language, aside from reflex cries, is just as untypical of all non-human forms of animal life. Like all other forms of human activity, language must have its history.

Much has been thought and written about the history of language. Under this term may be included two more or less distinct lines of inquiry. One may either trace the changes undergone by a particular language or group of languages for as long a period as the evidence at hand allows, or one may attempt to pass beyond the limits of historically recorded or reconstructed speech, to reconstruct the ultimate

[1] Lecture delivered at the University of Pennsylvania Museum, April 1, 1911.

origin of speech in general, and to connect these remote origins by means of reconstructed lines of development with historically attested forms of speech. Superficially the latter sort of inquiry is similar in spirit to the labors of the evolutionary biologist, for in both apparently heterogeneous masses of material are, by direct chronologic testimony, inference, analogy and speculation, reduced to an orderly historical sequence. As a matter of fact, however, the reconstruction of linguistic origins and earliest lines of development is totally different in kind from biological reconstruction, as we shall see presently.

Taking up the history of language in the sense in which it was first defined, we find that there are two methods by which we can follow the gradual changes that a language has undergone. The first and most obvious method is to study the literary remains of the various periods of the language of which we have record. It will then be found that not only the vocabulary, but just as well the phonetics, word morphology, and syntactic structure of the language tend to change from one period to another. These changes are always very gradual and, within a given period of relatively short duration, slight or even imperceptible in amount. Nevertheless, the cumulative effect of these slight linguistic changes is, with the lapse of time, so great that the form of speech current at a given time, when directly compared with the form of speech of the same language current at a considerably earlier time, is found to differ from the latter much as it might from a foreign language. It is true that the rate of change has been found to be more rapid at some periods of a language than at others, but it nevertheless always remains true that the changes themselves are not violent and sudden, but gradual in character. The documentary study of language history is of course the most valuable and, on the whole, the most satisfactory. It should not be denied, however, that there are dangers in its use. Literary monuments do not always accurately reflect the language of the period; moreover, orthographic conservatism hides the phonetic changes that are constantly taking place. Thus, there is no doubt that the amount of change that English has undergone from the time of Shakespeare to the present is far greater than a comparison of present-day with Elizabethan orthography would lead the layman to suppose, so much so that I am quite convinced the great dramatist would have no little difficulty in making himself understood in Stratford-on-Avon to-day. For some languages a considerable amount of documentary historical material is available; thus, the literary monuments that enable us to study the history of the English language succeed each other in a practically uninterrupted series from the eighth century A.D. to the present time, while the course of development of Greek in its various dialects can be more or less accurately followed from the ninth century B.C., a conservative date for the Homeric poems, to the present time.

For some, in fact for most languages, however, literary monuments are either not forthcoming at all or else are restricted to a single period of short duration. At first sight it would seem that the scientific study of such languages would have to be limited to purely descriptive rather than historical data. To a considerable extent this is necessarily true, yet an intensive study will always yield at least some, oftentimes a great deal of, information of a historical character. This historical reconstruction on the basis of purely descriptive data may proceed in two ways. It is obvious that the various phonetic and grammatical features of a language at any given time are of unequal antiquity, for they are the resultants of changes that have taken place at very different periods; hence it is reasonable to suppose that internal evidence would, at least within modest limits, enable one to reconstruct the relative chronology of the language. Naturally one must proceed very cautiously in reconstructing by means of internal evidence, but it is oftentimes surprising how much the careful and methodically schooled student can accomplish in this way. Generally speaking, linguistic features that are irregular in character may be considered as relatively archaic, for they are in the nature of survivals of features at one time more widely spread. Not infrequently an inference based on internal evidence can be corroborated by direct historical testimony. One example will suffice here. We have in English a mere sprinkling of noun plurals in *-en,* such as *brethren* and *oxen.* One may surmise that nouns such as these are but the last survivals of a type formerly existing in greater abundance, and indeed a study of Old English or Anglo-Saxon demonstrates that noun plurals in *-en* were originally found in great number but were later almost entirely replaced by plurals in *-s.* There is, however, a far more powerful method of reconstructing linguistic history from descriptive data than internal evidence. This is the comparison of genetically related languages.

In making a survey of the spoken languages of the world, we soon find that though they differ from each other, they do so in quite varying degrees. In some cases the differences are not great enough to prevent the speakers of the two languages from understanding each other with a fair degree of ease, under which circumstances we are apt to speak of the two forms of speech as dialects of a single language; in other cases the two languages are not mutually intelligible, but, as in the case of English and German, present so many similarities of detail that a belief in their common origin seems warranted and indeed necessary; in still other cases the two languages are at first glance not at all similar, but reveal on a closer study so many fundamental traits in common that there seems just ground for suspecting a common origin. If other languages can be found which serve to lessen the

chasm between the two, and particularly if it is possible to compare them in the form in which they existed in earlier periods, this suspicion of a common origin may be raised to a practical certainty. Thus, direct comparison of Russian and German would certainly yield enough lexical and grammatical similarities to justify one in suspecting them to have diverged from a common source; the proof of such genetic relationship, however, can not be considered quite satisfactory until the oldest forms of German speech and Germanic speech generally have been compared with the oldest forms of Slavic speech and until both of these have been further compared with other forms of speech, such as Latin and Greek, that there is reason to believe they are genetically related to. When such extensive, not infrequently difficult, comparisons have been effected, complete evidence may often be obtained of what in the first instance would have been merely suspected. If all the forms of speech that can be shown to be genetically related are taken together and carefully compared among themselves, it is obvious that much information will be inferred as to their earlier undocumented history; in favorable cases much of the hypothetical form of speech from which the available forms have diverged may be reconstructed with a considerable degree of certainty or plausibility. If under the term history of English we include not only documented but such reconstructed history as has been referred to, we can say that at least in main outline it is possible to trace the development of our language back from the present day to a period antedating at any rate 1500 B.C. It is important to note that, though the English of to-day bears only a faint resemblance to the hypothetical reconstructed Indogermanic speech of say 1500 B.C., there could never have been a moment from that time to the present when the continuity of the language was broken. From our present standpoint that bygone speech of 1500 B.C. was as much English as it was Greek or Sanskrit. The history of the modern English words *foot* and its plural *feet* will illustrate both the vast difference between the two forms of speech at either end of the series and the gradual character of the changes that have taken place within the series. Without here going into the actual evidence on which the reconstructions are based, I shall merely list the various forms which each word has had in the course of its history. Starting, then, with *foot—feet*, and gradually going back in time, we have *fūt—fīt, fōt—fēt, fōt—fēte, fōt—fōte, fōt—fōti, fōt—fōti, fōt—fōtir, fōt—fōtiz, fōt—fōtis, fōt—fōtes, fōd—fōdes,* and finally *pōd—pōdes,* beyond which our evidence does not allow us to go; the last forms find their reflex in Sanskrit *pād—pādas.*

All languages that can be shown to be genetically related, that is, to have sprung from a common source, form a historic unit to which the term linguistic stock or linguistic family is applied. If, now, we

were in a position to prove that all known forms of speech could be classified into a single linguistic stock, the apparent parallel above referred to between linguistic and biological reconstruction would be a genuine one. As it is, we must content ourselves with operating with distinct and, as far as we can tell, genetically unrelated linguistic stocks. The documentary evidence and the reconstructive evidence gained by comparison enable us to reduce the bewildering mass of known languages to a far smaller number of such larger stock groups, yet the absolute number of these latter groups still remains disquietingly large. The distribution of linguistic stocks presents great irregularities. In Europe there are only three such represented: the Indogermanic or Aryan, which embraces nearly all the better known languages of the continent; the Ural-Altaic, the best known representatives of which are Finnish, Hungarian and Turkish; and the Basque of southwestern France and northern Spain. On the other hand, that part of aboriginal North America which lies north of Mexico alone embraces fifty or more distinct linguistic stocks. Some stocks, as, for instance, the Indogermanic just referred to and the Algonkin of North America, are spread over vast areas and include many peoples or tribes of varying cultures; others, such as the Basque and many of the aboriginal stocks of California, occupy surprisingly small territories. It is possible to adopt one of two attitudes towards this phenomenon of the multiplicity of the largest known genetic speech aggregates. On the one hand one may assume that the disintegrating effects of gradual linguistic change have in many cases produced such widely differing forms of speech as to make their comparison for reconstructive purposes of no avail, in other words, that what appear to us to-day to be independent linguistic stocks appear such not because they are in fact historically unrelated, but merely because the evidence of such historical connection has been so obscured by time as to be practically lost. On the other hand, one may prefer to see in the existence of mutually independent linguistic stocks evidence of the independent beginnings and development of human speech at different times and places in the course of the remote history of mankind; there is every reason to believe that in a similar manner many religious concepts and other forms of human thought and activity found widely distributed in time and place have had multiple origins, yet more or less parallel developments. It is naturally fruitless to attempt to decide between the monogenetic and polygenetic standpoints here briefly outlined. All that a conservative student will care to do is to shrug his shoulders and to say, "Thus far we can go and no further." It should be said, however, that more intensive study of linguistic data is from time to time connecting stocks that had hitherto been looked upon as unrelated. Yet it can hardly be expected that serious research will ever succeed in reducing the present Babel to a pristine unity.

Although we can not demonstrate a genetic unity of all forms of human speech, it is interesting to observe that there are several fundamental traits that all languages have in common. Perhaps these fundamental similarities are worthy of greater attention than they generally receive and may be thought by many to possess a high degree of significance. First of all, we find that in every known language use is made of exactly the same organic apparatus for the production of speech, that is, the glottal passage in the larynx, the nasal passages, the tongue, the hard and soft palate, the teeth and the lips. The fact that we are accustomed to consider all speech as self-evidently dependent on these organs should not blind us to the importance of the association. There is, after all, no *à priori* reason why the communication of ideas should be primarily through sound symbols produced by the apparatus just defined; it is conceivable that a system of sound symbols of noises produced by the hands and feet might have been developed for the same purpose. As a matter of fact, there are many systems of thought transference or language in the widest sense of the word, as a moment's thought will show, that are independent of the use of the ordinary speech apparatus. The use of writing will occur to every one as the most striking example among ourselves. Among primitive peoples we may instance, to cite only a couple of examples of such subsidiary forms of language, the gesture language of the Plains Indians of North America and the very highly developed drum language of several African tribes. From our present point of view it is significant to note that these and other such non-spoken languages are either, as in the case of practically all systems of writing, themselves more or less dependent on a phonetic system, that is, speech in the ordinary sense of the word, or else are merely auxiliary systems intended to replace speech only under very special circumstances. The fact then remains that the primary and universal method of thought transference among human beings is *via* a special articulating set of organs. Much loose talk has been expended by certain ethnologists on the relatively important place that gesture occupies in the languages of primitive peoples, and it has even been asserted that several so-called primitive languages are unintelligible without the use of gesture. The truth, however, is doubtless that the use of gesture is associated not with primitiveness, but rather with temperament. The Russian Jew and the Italian, for instance, non-primitive as they are, make a far more liberal use of gestures accompanying speech than any of the aborigines of North America.

If we examine in a large way the structure of any given language, we find that it is further characterized by the use of a definite phonetic system, that is, the sounds made use of in its words are reducible to a limited number of consonants and vowels. It does not seem to be true,

certain contradicting statements notwithstanding, that languages are to be found in which this phonetic definiteness is lacking and in which individual variation of pronunciation takes place practically without limit. It is of course freely granted that a certain amount of sound variation exists in every language, but it is important to note that such variation is always very limited in range and always takes place about a well-defined center. All known forms of speech, then, operate with a definite apparatus of sounds; statements to the contrary will in most cases be found to rest either on a faulty perception on the part of the recorder of sounds unfamiliar to his ear or on his ignorance of regular sound processes peculiar to the language. Naturally the actual phonetic systems found in various languages, however much they may resemble each other in this fundamental trait of definiteness, differ greatly in content, that is in the sounds actually employed or neglected. This is inevitable, for the vast number of possible and indeed existing speech sounds makes an unconscious selection necessary. Even so, however, it is at least noteworthy with what persistency such simple vowel sounds as *a* and *i* and such consonants as *n* and *s* occur in all parts of the world.

Even more than in their phonetic systems languages are found to differ in their morphologies or grammatical structures. Yet also in this matter of grammatical structure a survey from a broad point of view discloses the fact that there are certain deep-lying similarities, very general and even vague in character, yet significant. To begin with, we find that each language is characterized by a definite and, however complex, yet strictly delimited grammatical system. Some languages exhibit a specific type of morphology with greater clearness or consistency than others, while some teem with irregularities; yet in every case the structure tends to be of a definite and consistently carried out type, the grammatical processes employed are quite limited in number and nearly always clearly developed, and the logical categories that are selected for grammatical treatment are of a definite sort and number and expressed in a limited, however large, number of grammatical elements. In regard to the actual content of the various morphologies, we find, as already indicated, vast differences, yet here again it is important to note with what persistence certain fundamental logical categories are reflected in the grammatical systems of practically all languages. Chief among these may be considered the clear-cut distinction everywhere made between denominating and predicating terms, that is between subject and predicate, or, roughly speaking, between substantive and verb. This does not necessarily imply that we have in all cases to deal with an actual difference in phonetic form between noun and verb, though as a matter of fact such differences are generally found, but simply that the structure of the sentence is such as to show

clearly that one member of it is felt by the speaker and hearer to have a purely denominating office, another a purely predicating one. It may be objected that in Chinese, for instance, there is no formal distinction made between noun and verb. True, but the logical distinction of subject and predicate is reflected in the form of the Chinese sentence, inasmuch as the subject regularly precedes the predicate; thus, while the same word *may* be either noun or verb, in any particular sentence it necessarily *is* definitely one and not the other. Other fundamental logical categories will, on a more complete survey, be found to be subject to grammatical treatment in all or nearly all languages, but this is not the place to be anything but merely suggestive. Suffice it to remark on the wide-spread systematizing of personal relations; the wide-spread development of ideas of tense, number and syntactic case relations; and the clear grammatical expression everywhere or nearly everywhere given to the largely emotional distinction of declarative, interrogative and imperative modes.

Granted that there are certain general fundamental traits of similarity in all known languages, the problem arises of how to explain these similarities. Are they to be explained historically, as survivals of features deep-rooted in an earliest form of human speech that, despite the enormous differentiation of language that the lapse of ages has wrought, have held their own to the present day, or are they to be explained psychologically as due to the existence of inherent human mental characteristics that abide regardless of time and race? If the latter standpoint be preferred, we should be dealing with a phenomenon of parallel development. It is of course impossible to decide categorically between the two explanations that have been offered, though doubtless the majority of students would incline to the psychological rather than to the historical method. At any rate, it is clear that we can not strictly infer a monogenetic theory of speech from the fundamental traits of similarity that all forms of speech exhibit. Yet even though these are of psychologic rather than historic interest, it is important to have demonstrated the existence of a common psychological substratum, or perhaps we had better say framework, which is more or less clearly evident in all languages. This very substratum or framework gives the scientific study of language a coherence and unity quite regardless of any considerations of genetic relationship of languages.

In spite of the fact that, as we have seen, no tangible evidence can be brought to bear on the ultimate origin or origins of speech, many attempts have been made, particularly in the first half of the nineteenth century, when it was more common for historical and philosophical problems of extreme difficulty to be attacked with alacrity, to point out the way in which human speech originated or at least might have originated. From the very nature of the case, these attempts could not but

be deductive in method; hence, however plausible or ingenious in themselves, they have at best a merely speculative, not a genuinely scientific interest. We may therefore dispense with anything like a detailed inquiry into or criticism of these theories. Two of the most popular of them may be respectively termed the onomatopoetic or sound-imitative and the exclamatory theories. According to the former, the first words of speech were onomatopoetic in character, that is, attempts to imitate by the medium of the human organs of speech, the various cries and noises of the animate and inanimate world. Thus, the idea of a "hawk" would come to be expressed by an imitative vocable based on the actual screech of that bird; the idea of a "rock" might be expressed by a combination of sounds intended in a crude way to reproduce the noise of a rock tumbling down hill or of a rock striking against the butt of a tree; and so on indefinitely. In course of time, as these imitative words by repeated use became more definitely fixed in phonetic form, they would tend to take on more and more the character of conventional sound-symbols, that is of words, properly speaking. The gradual phonetic modifications brought on in the further course of time would finally cause them to lose their original onomatopoetic form. It may be freely granted that many words, particularly certain nouns and verbs having reference to auditory phenomena, may have originated in this way; indeed, many languages, among them English, have at various times, up to and including the present, made use of such onomatopoetic words. It is difficult, however, to see how the great mass of a vocabulary, let alone a complex system of morphology and syntax, could have arisen from an onomatopoetic source alone. The very fact that onomatopoetic words of relatively recent origin are found here and there in sharp contrast to the overwhelmingly larger non-onomatopoetic portion of the language accentuates, if anything, the difficulty of a general explanation of linguistic origins by means of the onomatopoetic theory.

The exclamatory theory, as its name implies, would find the earliest form of speech in reflex cries of an emotional character. These also, like the hypothetical earliest words of imitative origin, would in course of time become conventionalized and sooner or later so modified in phonetic form as no longer to betray their exclamatory origin. The criticisms urged against the onomatopoetic theory apply with perhaps even greater force to the exclamatory one. It is, if anything, even more difficult here than in the former case to see how a small vocabulary founded on reflex cries could develop into such complex linguistic systems as we have actually to deal with. It is further significant that hardly anywhere, if at all, do the interjections play any but an inconsiderable, almost negligible, part in the lexical or grammatical machinery of language. An appeal to the languages of primitive peoples

in order to find in them support for either of the two theories referred to is of little or no avail. Aside from the fact that their elaborateness of structure often seriously militates against our accepting them as evidence for primitive conditions, we do not on the whole find either the onomatopoetic or exclamatory elements of relatively greater importance in them than elsewhere. Indeed the layman would be often surprised, not to say disappointed, at the almost total absence of onomatopoetic traits in many American Indian languages, for instance. In Chinook and related dialects of the lower course of the Columbia, onomatopoesis is developed to a more than usual extent, yet, as though to emphasize our contention with an apparent paradox, hardly anywhere is the grammatical mechanism of a subtler, anything but primitive character. We are forced to conclude that the existence of onomatopoetic and exclamatory features is as little correlated with relative primitiveness as we have found the use of gesture to be. As with the two theories of origin we have thus briefly examined, so it will be found to be with other theories that have been suggested. They can not, any of them, derive support from the use of the argument of survivals in historically known languages; they all reduce themselves to merely speculative doctrines.

So much for general considerations on language history. Returning to the gradual process of change which has been seen to be characteristic of all speech, we may ask ourselves what is the most central or basic factor in this never-ceasing flux. Undoubtedly the answer must be: phonetic change or, to put it somewhat more concretely, minute or at any rate relatively trivial changes in pronunciation of vowels and consonants which, having crept in somehow or other, assert themselves more and more and end by replacing the older pronunciation, which becomes old-fashioned and finally extinct. In a general way we can understand why changes in pronunciation should take place in the course of time by a brief consideration of the process of language learning. Roughly speaking, we learn to speak our mother-tongue by imitating the daily speech of those who surround us in our childhood. On second thoughts, however, it will be seen that the process involved is not one of direct imitation, but of indirect imitation based on inference. Any given word is pronounced by a succession of various more or less complicated adjustments of the speech organs. These adjustments or articulations give rise to definite acoustic effects, effects which, in their totality, constitute speech. Obviously, if the child's imitative efforts were direct, it would have to copy as closely as possible the speech articulations which are the direct source of what it hears. But it is still more obvious that these speech articulations are largely beyond the power of observation and hence imitation. It follows that the actual sounds, not the articulations producing them, are imitated. This

means that the child is subject to a very considerable period of random and, of course, wholly involuntary experimenting in the production of such articulations as would tend to produce sounds or combinations of sounds approximating more or less closely those the child hears. In the course of this experimenting many failures are produced, many partial successes. The articulations producing the former, inasmuch as they do not give results that match the sounds which it was intended to imitate, have little or no associative power with these sounds, hence do not readily form into habits; on the other hand, articulations that produce successes or comparative successes will naturally tend to become habitual. It is easy to see that the indirect manner in which speech articulations are acquired necessitates an element of error, very slight, it may be, but error nevertheless. The habitual articulations that have established themselves in the speech of the child will yield auditory results that approximate so closely to those used in speech by its elders, that no need for correction will be felt. And yet it is inevitable that the sounds, at least some of the sounds, actually pronounced by the child will differ to a minute extent from the corresponding sounds pronounced by these elders. Inasmuch as every word is composed of a definite number of sounds and as, furthermore, the language makes use of only a limited number of sounds, it follows that corresponding to every sound of the language a definite articulation will have become habitual in the speech of the child; it follows immediately that the slight phonetic modifications which the child has introduced into the words it uses are consistent and regular. Thus if a vowel *a* has assumed a slightly different acoustic shade in one word, it will have assumed the same shade in all other cases involving the old *a*-vowel used by its elders, at any rate in all other cases in which the old *a*-vowel appears under parallel phonetic circumstances.

Here at the very outset we have illustrated in the individual the regularity of what have come to be called phonetic laws. The term "phonetic *law*" is justified in so far as a common tendency is to be discovered in a large number of individual sound changes. It is important, however, to understand that phonetic law is a purely historic concept, not one comparable to the laws of natural science. The latter may be said to operate regardless of particular times and places, while a phonetic law is merely a generalized statement of a process that took place in a restricted area within a definite period of time. The real difficulty in the understanding of phonetic change in language lies not in the fact of change itself, nor in the regularity with which such change proceeds in all cases affected, but, above all, in the fact that phonetic changes are not merely individual, but social phenomena; in other words, that the speech of all the members of a community in a given time and place undergoes certain regular phonetic changes. Without here attempting

to go into the details of this process of the transformation of an individual phonetic peculiarity into a social one, we will doubtless not be far wrong in assuming that uniformity is at first brought about by a process of unconscious imitation, mutual to some extent, among the younger speakers of a restricted locality, later, perhaps, by the half-conscious adoption of the new speech peculiarity by speakers of neighboring localities, until, finally, it has spread either over the entire area in which the language is spoken or over some definite portion of it. In the former case the historic continuity of the language as a unit is preserved, in the latter a dialectic peculiarity has asserted itself. In the course of time other phonetic peculiarities spread that serve to accentuate the dialectic division. However, the ranges of operation of the different phonetic laws need not be coterminous, so that a network of dialectic groupings may develop. At least some of the dialects will diverge phonetically more and more, until in the end forms of speech will have developed that deserve to be called distinct languages. It can not be denied that, particularly after a considerable degree of divergence has been attained, other than purely phonetic characteristics develop to accentuate a difference of dialect, but every linguistic student is aware of the fact that the most easily formulated and, on the whole, the most characteristic differences between dialects and between languages of the same genetic group are phonetic in character.

True, some one will say, changes of a purely phonetic character can be shown to be of importance in the history of language, but what of changes of a grammatical sort? Are they not of equal or even greater importance? Strange as it may seem at first blush, it can be demonstrated that many, perhaps most, changes in grammatical form are at last analysis due to the operation of phonetic laws. Inasmuch as these phonetic laws affect the phonetic form of grammatical elements as well as of other linguistic material, it follows that such elements may get to have a new bearing, as it were, brought about by their change in actual phonetic content; in certain cases, what was originally a single grammatical element may in this way come to have two distinct forms, in other cases two originally distinct grammatical elements may come to have the same phonetic appearance, so that if circumstances are favorable, the way is paved for confusion and readjustment. Briefly stated, phonetic change may and often does necessitate a readjustment of morphologic groupings. It will be well to give an example or two from the history of the English language. In another connection we have had occasion to briefly review the history of the words *foot* and *feet*. We saw that there was a time when these words had respectively the form *fōt* and *fōti*. The final *i*-vowel of the second word colored, by a process of assimilation which is generally referred to as "umlaut," the *ō* of the first syllable and made it *ö*, later unrounded to *ē*; the final

i, after being dulled to an *e*, finally dropped off altogether. The form *fōti* thus step by step developed into the later *fēt*, which is the normal Anglo-Saxon form. Note the result. In *fōti* and other words of its type the plural is expressed by a distinct suffix *-i*, in *fēt*, as in modern English *feet*, and in words of corresponding form it is expressed by an internal change of vowel. Thus an entirely new grammatical feature in English, as also in quite parallel fashion in German, was brought about by a series of purely phonetic changes, in themselves of no grammatical significance whatever.

Such grammatical developments on the basis of phonetic changes have occurred with great frequency in the history of language. In the long run, not only may in this way old grammatical features be lost and new ones evolved, but the entire morphologic type of the language may undergo profound modification. A striking example is furnished again by the history of the English language. It is a well-known feature of English that absolutely the same word, phonetically speaking, may often, according to its syntactic employment, be construed as verb or as noun. Thus we not only *love* and *kiss*, but we also give our *love* or a *kiss*, that is, the words *love* and *kiss* may be indifferently used to predicate or to denominate an activity. There are so many examples in English of the formal, though not syntactic, identity of noun stem and verb stem that it may well be said that the English language is on the way to become of a purely analytic or isolating type, more or less similar to that of Chinese. And yet the typical Indogermanic language of earlier times, as represented say by Latin or Greek, always makes a rigidly formal, not merely syntactic, distinction between these fundamental parts of speech. If we examine the history of this truly significant change of type in English, we shall find that it has been due at last analysis to the operation of merely phonetic laws. The original Anglo-Saxon form of the infinitive of the verb *kiss* was *cyssan*, while the Anglo-Saxon form of the noun *kiss* was *cyss*. The forms in early middle English times became dulled to *kissen* and *kiss*, respectively. Final unaccented *-n* later regularly dropped off, so that the infinitive of the verb came to be *kisse*. In Chaucer's day the verb and the noun were still kept apart as *kisse* and *kiss*, respectively; later on, as a final unaccented *-e* regularly dropped off, *kisse* became *kiss*, so that there ceased to be any formal difference between the verb and noun. The history of the Anglo-Saxon verb *lufian* "to love" and noun *lufu* "love" has been quite parallel; the two finally became confused in a single form *luv*, modern English *love*. Once the pace has been set, so to speak, for an interchange in English between verbal and nominal use of the same word, the process, by the working of simple analogy, is made to apply also to cases where in origin we have to deal with only one part of speech; thus we may not only have a sick *stomach*,

but we may *stomach* an injury (noun becomes verb), and conversely we may not only *write up* a person, but he may get a *write up* (verb becomes noun). It has, I hope, become quite clear by this time how the trivial changes of pronunciation that are necessitated by the very process of speech acquirement may, in due course of time, profoundly change the fundamental characteristics of language. So also, if I may be pardoned the use of a simile, may the slow erosive action of water, continued through weary ages, profoundly transform the character of a landscape. If there is one point of historic method rather than another that the scientific study of language may teach other historical sciences, it is that changes of the greatest magnitude may often be traced to phenomena or processes of a minimal magnitude.

On the whole, phonetic change may be said to be a destructive or at best transforming force in the history of language. Reference has already been made to the influence of analogy, which may, on the contrary, be considered a preservative and creative force. In every language the existing morphological groups establish more or less definite paths of analogy to which all or practically all the lexical material is subjected; thus a recently acquired verb like *to telegraph* in English is handled in strict analogy to the great mass of old verbs with their varying forms. Such forms as *he walks* and *he laughs* set the precedent for *he telegraphs,* forms like *walking* and *laughing* for *telegraphing.* Without such clear-cut grooves of analogy, indeed, it would be impossible to learn to speak, a corollary of which is that there is a limit to the extent of grammatical irregularity in any language. When, for some reason or other, as by the disintegrating action of phonetic laws, too great irregularity manifests itself in the morphology of the language, the force of analogy may assert itself to establish comparative regularity, that is, forms which belong to ill-defined or sparsely represented morphologic groups may be replaced by equivalent forms that follow the analogy of better-defined or more numerously represented groups. In this way all the noun plurals of English, if we except a few survivals like *feet* and *oxen,* have come to be characterized by a suffixed *-s;* the analogical power of the old *-s* plurals was strong enough to transform all other plurals, of which Anglo-Saxon possessed several distinct types. The great power exerted by analogy is seen in the persistence with which children, whose minds are naturally unbiased by tradition, use such forms as *foots* and *he swimmed.* Let us not smile too condescendingly at the use of such forms; it may not be going too far to say that there is hardly a word, form, or sound in present-day English which was not at its first appearance looked upon as incorrect.

The disintegrating influence of phonetic change and the leveling influence of analogy are perhaps the two main forces that make for linguistic change. The various influences, however, that one language

may exert upon another, generally summed up in the word borrowing, are also apt to be of importance. As a rule such influence is limited to the taking over or borrowing of certain words of one language by another, the phonetic form of the foreign word almost always adapting itself to the phonetic system of the borrowing language. Besides this very obvious sort of influence, there are more subtle ways in which one language may influence another. It is a very noteworthy phenomenon that the languages of a continuous area, even if genetically unrelated and however much they may differ among themselves from the point of view of morphology, tend to have similar phonetic systems or, at any rate, tend to possess certain distinctive phonetic traits in common. It can not be accidental, for instance, that both the Slavic languages and some of the neighboring but absolutely unrelated Ural-Altaic languages (such as the Cheremiss of the Volga region) have in common a peculiar dull vowel, known in Russian as *yerí,* and also a set of palatalized or so-called "soft" consonants alongside a parallel set of unpalatalized or so-called "hard" consonants. Similarly, we find that Chinese and Siamese have in common with the unrelated Annamite and certain other languages of Farther India a system of musical accent. A third very striking example is afforded by a large number of American Indian linguistic stocks reaching along the Pacific coast from southern Alaska well into California and beyond, which have in common peculiar voiceless *l*-sounds and a set of so-called "fortis" consonants with cracked acoustic effect. It is obvious that in all these cases of comparatively uniform phonetic areas embracing at the same time diverse linguistic stocks and types of morphology we must be dealing with some sort of phonetic influence that one language may exert upon another. It may also be shown, though perhaps less frequently, that some of the morphologic traits of one language may be adopted by a neighboring, sometimes quite unrelated, language, or that certain fundamental grammatical features are spread among several unrelated linguistic stocks of a continuous area. One example of this sort of influence will serve for many. The French express the numbers 70, 80 and 90, respectively, by terms meaning 60-10, 4 twenties and 4 twenties 10; these numerals, to which there is no analogy in Latin, have been plausibly explained as survivals of a vigesimal method of counting, that is counting by twenties, the numbers above 20, a method that would seem to have been borrowed from Gallic, a Celtic language, and which still survives in Gaelic and other modern Celtic languages. This example is the more striking as the actual lexical influence which Celtic has exerted upon French is surprisingly small. So much for the influence of borrowing on the history of a language.

We may turn now to take up the matter of the varieties of human speech. One method of classifying the languages of the world has been

already referred to; it may be termed the genetic method, inasmuch as it employs as its criterion of classification the demonstrable relation of certain languages as divergent forms of some older form of speech. As we have already seen, the linguistic stocks which we thus get as our largest units of speech are too numerous to serve as the simplest possible reduction of the linguistic material to be classified. One naturally turns, therefore, to a psychological classification, one in which the classificatory criterion is the fundamental morphological type to which a particular language or stock is to be assigned. Such a classification of morphological types may proceed from different points of view, varying emphasis being laid on this or that feature of morphology. It is clear at the outset that we have to distinguish between what we may call the subject-matter or content of morphology and the mere form pure and simple. Any grammatical system gives formal expression to certain modes or categories of thought, but the manner of expression of these categories or the formal method employed may vary greatly both for different categories and for different languages. Not infrequently the same logical category may be expressed by different formal methods in the same language. Thus, in English, the negative idea is expressed by means of three distinct formal methods exemplified by *untruthful,* with its use of a prefix *un-,* which can not occur as a freely movable word; *hopeless,* with its use of a suffix *-less,* which again can not occur as a freely movable word; and *not good,* in which the negative idea is expressed by an element (*not*) that has enough mobility to justify its being considered an independent word. We have here, then, three formal processes illustrated to which may be assigned the terms prefixing, suffixing and juxtaposing in definite order. While the same logical category may be grammatically expressed by different formal methods, it is even more evident that the same general formal method may be utilized for many different categories of thought. Thus, in English, the words *books* and *worked* use the same method of suffixing grammatical elements, the one to express the concept of plurality, the other that of past activity. The words *feet* and *swam,* furthermore, respectively express the same two concepts by the use of an entirely distinct formal method, that of internal vowel change.

On the whole one finds that it is possible to distinguish between two groups of grammatically expressed logical categories. One group may be characterized as derivational; it embraces a range of concepts expressed by grammatical elements that serve to limit or modify the signification of the word subjected to grammatical treatment without seriously affecting its relation to other words in the sentence. Such merely derivational elements are, in English, prefixes like *un-,* suffixes like *-less,* agentive suffixes like *-er* in *baker,* and numerous others. The second group of logical concepts and corresponding grammatical ele-

ments may be characterized as relational; they not merely serve to give the word affected a new increment of meaning, as is the case with the first group, but also assign it a definite syntactic place in the sentence, defining as they do its relation to other words of the sentence. Such a relational grammatical element, in English, is the plural *-s* suffix; a word, for instance, like *books* differs from its corresponding singular *book* not merely in the idea of plurality conveyed by the suffix *-s*, but assumes a different grammatical relation to other words in the sentence —a book *is*, but books *are*. Such relational elements are, furthermore, the case and gender suffixes of nouns and adjectives in Indogermanic languages; furthermore, the personal endings and tense suffixes of verbs. On the whole it may be said that derivational elements are of relatively more concrete signification than the relational ones and tend to become more thoroughly welded into a word unit with the basic word or stem to which they are attached or which they affect. This statement, however, is only approximately of general application and is subject to numerous qualifications. The greatest degree of concreteness of meaning conveyed by derivational elements is probably attained in many, though by no means all, American Indian languages, where ideas of largely material content are apt to be expressed by grammatical means. To this tendency the name of polysynthesis has been applied. Thus in Yana, an Indian language of northern California, such ideas as up a hill, across a creek, in the fire, to the east, from the south, immediately, in vain and a host of others are expressed by means of grammatical suffixes appended to the verb stem; so also in Nootka, an Indian language of Vancouver Island, so highly special ideas as on the head, in the hand, on the rocks, on the surface of the water, and many others, are similarly expressed as suffixes. It is important to note that, although the distinction between derivational and relational grammatical elements we have made is clearly reflected in some way or other in most languages, they differ a great deal as to what particular logical concepts are treated as respectively derivational or relational. Such concepts as those of sex gender, number and tense, which in Indogermanic are expressed as relational elements, are in other linguistic stocks hardly to be separated, as regards their grammatical treatment, from concepts treated in a clearly derivational manner. On the other hand, demonstrative ideas, which in most Indogermanic languages receive no relational syntactic treatment, may, as in the Kwakiutl language of British Columbia, serve an important relational function, analogous, say, to the Indogermanic use of gender; just as in Latin, for instance, such a sentence as "I saw the big house" is expressed by "I-saw house-masculine-objective big-masculine-objective," with a necessary double reference to the concepts of case relation and gender, so in Kwakiutl the sentence "I saw the house" would have to be ex-

pressed by some such sentence as "I-saw-the-objective-near-you house-visible-near-you," with an analogous necessary double reference to the demonstrative relations involved. If, now, it has been shown that no necessary correlation exists between particular logical concepts and the formal method of their grammatical rendering, and if, furthermore, there can not even be shown to be a hard and fast line in grammatical treatment between concepts of a derivational and concepts of a more definitely relational character, what becomes of the logical category *per se* as a criterion of linguistic classification on the basis of form? Evidently it fails us. Of however great psychological interest it might be to map out the distribution in various linguistic stocks of logical concepts receiving formal treatment, it is clear that no satisfactory formal classification of linguistic types would result from such a mapping.

Having thus disposed of the subject-matter of linguistic morphology as a classificatory criterion, there is left to us the form pure and simple. Here we are confronted first of all by a number of formal grammatical methods or processes. These, being less numerous than the logical categories which they express themselves, and, furthermore, being on the whole more easily defined and recognized, would seem to lend themselves more easily to classificatory purposes. The simplest grammatical process is the *juxtaposing of words in a definite order,* a method made use of to perhaps the greatest extent by Chinese, to a very large extent also by English; the possibilities of the process from the point of view of grammatical effectiveness may be illustrated by comparing such an English sentence as "The man killed the bear" with "The bear killed the man," the actual words and forms being identical in the two sentences, yet definite case relations being clearly expressed in both. A somewhat similar process, yet easily enough kept apart, is *compounding,* that is, the fusion of two words or independent stems, into a firm word-unit; the process is particularly well developed in English, as illustrated by words like *railroad* and *underestimate,* and indeed is found widely spread among the most diverse linguistic stocks. In some languages, as in the Sioux and Paiute of our own country, compounding of verb stems is frequent, as illustrated by such forms as *to eat-stand,* that is *to eat while standing;* on the other hand, in not a few linguistic stocks, as the wide-spread Athabascan stock of North America and the Semitic languages, compounding as a regular process is almost or entirely lacking. Perhaps the most commonly used formal method of all is *affixing,* that is, the appending of grammatical elements to a word or to the body or stem of a word; the two most common varieties of affixing are prefixing and suffixing, examples of which have been already given from English. Probably the majority of linguistic stocks make use of both prefixes and suffixes, though

they differ greatly as to the relative importance to be attached to these two classes of elements. Thus, while both in Indogermanic and in the Bantu languages of Africa prefixes and suffixes are to be found, we must note that the greater part of the grammatical machinery of Indogermanic is carried on by its suffixes, while it is the prefixes that in Bantu take the lion's share of grammatical work. There are also not a few linguistic stocks in which suffixing as a process is greatly developed, while prefixing is entirely unknown; such are Ural-Altaic, Eskimo, and the Kwakiutl and Nootka languages of British Columbia. On the other hand, languages in which prefixes are used, but no suffixes, seem to be quite rare. A third variety of affixing, known as infixing, consists in inserting a grammatical element into the very body of a stem; though not nearly so wide-spread as either prefixing or suffixing, it is a well-attested linguistic device in Malayan, Siouan, and elsewhere. Still another wide-spread grammatical process is *reduplication,* that is, the repetition of the whole or, generally, only part of the stem of a word; in Indogermanic we are familiar with this process in the formation, for instance, of the Greek perfect, while in many American Indian languages, though in far from all, the process is used to denote repeated activity. Of a more subtle character than the grammatical processes briefly reviewed thus far is *internal vowel* or *consonant change.* The former of these has been already exemplified by the English words *feet* and *swam* as contrasted with *foot* and *swim;* it attains perhaps its greatest degree of development in the Semitic languages. The latter, internal consonant change, is on the whole a somewhat rare phenomenon, yet finds an illustration in English in at least one group of cases. Beside such nouns as *house, mouse,* and *teeth* we have derived verbs such as *to house, mouse around,* and *teeth;* in other words a certain class of verbs is derived from corresponding nouns by the changing of the final voiceless consonants of the latter to the corresponding voiced consonants. In several non-Indogermanic linguistic stocks, as in Takelma of southwestern Oregon and in Fulbe of the Soudan, such grammatical consonant changes play a very important part. As the last formal grammatical process of importance may be mentioned *accent,* and here we have to distinguish between stress accent and musical or pitch accent. An excellent example of the grammatical use of stress accent is afforded in English by such pairs of words as *cónflict* and *conflíct, óbject* and *objéct,* the verb being accented on the second syllable, the noun on the first. Musical accent is a far more prevalent phonetic characteristic than is perhaps generally supposed; it is by no means confined to Chinese and neighboring languages of eastern Asia, but is found just as well in many languages of Africa and, as has been recently discovered by Mr. J. P. Harrington and the writer, in a few North American Indian

languages. As a process of definite grammatical significance, however, musical accent is not so wide-spread. It is found, to give but one example, in the earlier stages of Indogermanic, as exemplified, among others, by classical Greek and by Lithuanian.

Having thus briefly reviewed the various grammatical processes used by different languages, we may ask ourselves whether the mapping out of the distribution of these processes would be of more service to us in our quest of the main types of language than we have found the grammatical treatment of logical concepts to be. Here a difficulty presents itself. If each linguistic stock were characterized by the use of just one or almost entirely one formal process, it would not be difficult to classify all languages rather satisfactorily on the basis of form. But there are great differences in this respect. A minority of linguistic stocks content themselves with a consistent and thoroughgoing use of one process, as does Eskimo with its suffixing of grammatical elements, but by far the larger number make use of so many that their classification becomes difficult, not to say arbitrary. Thus in Greek alone every one of the processes named above, excepting consonant change, can be exemplified. Even if we limit ourselves to a consideration of grammatical processes employed to express the relational concepts, we shall find the same difficulty, for the same language not infrequently makes use of several distinct processes for concepts of this class.

On a closer study of linguistic morphology, however, we find that it is possible to look at the matter of form in language from a different, at the same time more generalized, point of view than from that of the formal processes employed themselves. This new point of view has regard to the inner coherence of the words produced by the operation of the various grammatical processes, in other words, to the relative degree of unity which the stem or unmodified word plus its various grammatical increments or modifications possesses, emphasis being particularly laid on the degree of unity which the grammatical processes bring about between the stem and the increments which express relational concepts. On the basis of this formal criterion we may classify languages, at least for the purposes of this paper, into the three main types of linguistic morphology generally recognized. The first type is characterized by the use of words which allow of no grammatical modification whatever, in other words the so-called *isolating* type. In a language of this type all relational concepts are expressed by means of the one simple device of juxtaposing words in a definite order, the words themselves remaining unchangeable units that, according to their position in the sentence, receive various relational values. The classical example of such a language is Chinese, an illustration from which will serve as an example of the isolating type of

sentence. *wo͡o*^{3} (rising from deep tone) *pū*^{2} (rising from high) *p'ā*^{4} (sinking from middle) *t'ā*^{1} (high) may be literally translated "I not fear he," meaning "I do not fear him"; *wo͡o*^{3} "I" as subject comes first; *p'ā*^{4} "fear" as predicate follows it; *pū*^{2} "not," inasmuch as it limits the range of meaning given by the predicate, must precede it, hence stands between the subject and predicate; finally *t'ā*^{2} "he" as object follows the predicate. If we exchange the positions of *wo͡o*^{3} and *t'ā*^{1} we change their syntactical bearing; *wo͡o*^{3} "I" becomes "me" as object, while *t'ā*^{1}, which in our first sentence was best translated as "him" now becomes "he" as subject, and the sentence now takes on the meaning of "he does not fear me."

In the second main type of language, generally known as the *agglutinative,* the words are not generally unanalyzable entities, as in Chinese, but consist of a stem or radical portion and one or more grammatical elements which partly modify its primary signification, partly define its relation to other words in the sentence. While these grammatical elements are in no sense independent words or capable of being understood apart from their proper use as subordinate parts of a whole, they have, as a rule, their definite signification and are used with quasi-mechanical regularity whenever it is considered grammatically necessary to express the corresponding logical concept; the result is that the word, though a unit, is a clearly segmented one comparable to a mosaic. An example taken from Turkish, a typical agglutinative language, will give some idea of the spirit of the type it represents. The English sentence "They were converted into the (true) faith with heart and soul" is rendered in Turkish *džan u gönül-den iman-a gel-ir-ler*[2] literally translated, "Heart and soul-from belief-to come-ing-plural." The case-ending *-den* "from" is here appended only to *gönül* "soul" and not to *džan* "heart," though it applies equally to both; here we see quite clearly that a case-ending is not indissolubly connected with the noun to which it is appended, but has a considerable degree of mobility and corresponding transparency of meaning. The verb form *gel-ir-ler,* which may be roughly translated as "they come," is also instructive from our present point of view; the ending *-ler* or *-lar* is quite mechanically used to indicate the concept of plurality, whether in noun or verb, so that a verb form "they come," really "come-plural," is to some extent parallel to a noun form like "books," really "book-plural." Here we see clearly the mechanical regularity with which a logical concept and its corresponding grammatical element are associated.

In the third, the *inflective,* type of language, while a word may be analyzed into a radical portion and a number of subordinate gram-

[2] The Turkish and Chinese examples are taken from F. N. Fisk's "Die Haupttypen des Sprachbaus."

matical elements, it is to be noted that the unity formed by the two is a very firm one, moreover that there is by no means a mechanical one-to-one correspondence between concept and grammatical element. An example from Latin, a typical inflective language, will illustrate the difference between the agglutinative and inflective types. In a sentence like *videō hominēs* "I see the men," it is true that the verb form *videō* may be analyzed into a radical portion *vide-* and a personal ending *-ō,* also that the noun form *hominēs* may be analyzed into a radical portion *homin-* and an ending *-ēs* which combines the concepts of plurality with objectivity, that is, a concept of number with one of case. But, and here comes the significant point, these words, when stripped of their endings, cease to have even a semblance of meaning, in other words, the endings are not merely agglutinated on to fully-formed words, but form firm word-units with the stems to which they are attached; the absolute or rather subjective form *homō,* "man," is quite distinct from the stem *homin-* which we have obtained by analysis. Moreover, it should be noted that the ending *-ō* is not mechanically associated with the concept of subjectivity of the first person singular, as is evidenced by such forms as *vīdī* "I saw" and *videam* "I may see"; in the ending *-ēs* of *hominēs* the lack of the mechanical association I have spoken of is even more pronounced, for not only are there in Latin many other noun endings which perform the same function, but the ending does not even express a single concept, but, as we have seen, a combined one.

The term *polysynthetic* is often employed to designate a fourth type of language represented chiefly in aboriginal America, but, as has been shown in another connection, it refers rather to the content of a morphologic system than to its form, and hence is not strictly parallel as a classificatory term to the three we have just examined. As a matter of fact, there are *polysynthetic* languages in America which are at the same time agglutinative, others which are at the same time inflective.

It should be carefully borne in mind that the terms isolating, agglutinative and inflective make no necessary implications as to the logical concepts the language makes use of in its grammatical system, nor is it possible definitely to associate these three types with particular formal processes. It is clear, however, that on the whole languages which make use of word order only for grammatical purposes are isolating in type, further, that languages that make a liberal grammatical use of internal vowel or consonant change may be suspected of being inflective. It was quite customary formerly to look upon the three main types of morphology as steps in a process of historical development, the isolating type representing the most primitive form of speech at which it was possible to arrive, the agglutinative coming next in order as a type

evolved from the isolating, and the inflective as the latest and so-called highest type of all. Further study, however, has shown that there is little to support this theory of evolution of types. The Chinese language, for instance, so far from being typical of a primitive stage, as used to be asserted, has been quite conclusively proven by internal and comparative evidence to be the resultant of a long process of simplification from an agglutinative type of language. English itself, in its historical affiliations an inflective language, has ceased to be a clear example of the inflective type and may perhaps be said to be an isolating language in the making. Nor should we be too hasty in attaching values to the various types and, as is too often done even to-day, look with contempt on the isolating, condescendingly tolerate the agglutinative, and vaunt the superiority of the inflective type. A well-developed agglutinative language may display a more logical system than the typically inflective language. And as for myself, I should not find it ridiculous or even paradoxical if one asserted that the most perfect linguistic form, at least from the point of view of logic, had been attained by Chinese, for here we have a language that, with the simplest possible means at its disposal, can express the most technical or philosophical ideas with absolute lack of ambiguity and with admirable conciseness and directness.

UNIVERSITY STANDARDS AND STUDENT ACTIVITIES

By ORRIN LESLIE ELLIOTT

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IN a recent address before the Stanford Forum Professor Barrows made reference to the current criticism and depreciation of the American college. This criticism may be summed up in the statement that the college does not make good. Its output is woefully disappointing. Its business is to prepare young men and women for effective living in their time and place, to equip them for the responsibilities and duties which every generation in turn must meet and discharge if the standards of civilization are to be maintained and pushed forward. The charge is that college graduates do not meet the test; they do not measure up to the requirements; they are deficient in those very qualities which the higher education is supposed especially to nurture.

Professor Barrows would frankly accept the situation: the fact is mainly true; the explanation is that too much has been expected of the college. College students are too immature. As one goes about the campus it is groups of boys and girls that he meets, full of the play-time spirit, not taking learning seriously, their minds filled with games and social functions. Better recognize that it is so, consider the college period as an extension of the playground, and not expect of it equipment for the serious part of life.

Professor Barrows was holding a brief for the graduate school, whose function should be, as he conceived it, to do exactly what it is unreasonable to expect of the undergraduate college. That point I do not wish to follow. But that which Professor Barrows passed off carelessly as an added argument for the graduate school may well be the object of further inquiry. If it is true that the college has failed there is something pathetic in the situation thus presented; because education is the one thing to which democracy has pinned its faith. And the outward progress of education has been all and more than its wildest enthusiasts could have dreamed. From kindergarten to university the wealth of the state has been poured out, and the state's bounty supplemented by unparalleled private munificence, until the highest education is within reach of the humblest youth in the land. Within a single generation, while population has increased but a hundred per cent., the attendance upon institutions of higher education has increased four hundred per cent. The expansion in secondary education has been no less significant. In 1880 there were no four-year high schools in the

United States, and the whole number of secondary schools, public and private, was only 1,400. In 1907 the number had risen to 10,238, an increase of over 700 per cent. And the modern high-school course comprehends a broader training than was given by the college of fifty years ago! Everything would seem to be prepared for college work of the highest efficiency.

By common admission, quite the contrary is the case. Different colleges are differently affected, but the same virus has found its way to all. "The college has lost its definiteness of aim," says ex-President Woodrow Wilson. "There is no question," affirms Mr. Flexner, "that the college is under fire. . . . The college faces the new and unforeseen problems rather helplessly. It is bewildered. . . . Unless I greatly err, the college has already lost a trick or two." "Notwithstanding the enormous improvement and growth in machinery, plant and facilities of our colleges," declares Mr. Birdseye, "their methods and systems are archaic and the average of their product—from the point of good workmanship—has decidedly deteriorated." "The important thing"—I quote from Flexner's "American College"—"is to realize that the American college is deficient, and unnecessarily deficient, alike in earnestness and in pedagogical intelligence; that in consequence our college students are, and for the most part, emerge, flighty, superficial, and immature, lacking, as a class, concentration, seriousness and thoroughness. . . . A youth may win his degree on a showing that would in an office cost him his desk." There is "on the one side a formidable array of scholars and scientists, libraries, laboratories, publications; on the other, a large miscellaneous student body, marked by an immense sociability on a commonplace basis and wide-spread absorption in trivial and boyish interests. How are we to account for the disparity? Clearly the college fails to enlist a respectable portion of the youth's total energy in intellectual effort; either its sincerity or its pedagogical intelligence is discredited by the occupations and diversions which it finds not incompatible with its standards and expectations." "So far as the colleges are concerned," says Professor Münsterberg, "one imperative change stands in the center of every platform: scholarship must receive a more dignified standing in the eyes of the undergraduates. . . . So long as the best human material in our colleges considers it as more or less below its level to exert effort on its studies; so long as it gladly leaves the high marks to the second-rate grinds, and considers it the part of a real gentleman to spend four years with work done well enough not to be dismissed, and poorly enough never to excel, there is something vitally wrong in the academic atmosphere." President Lowell, in a recent address before the University Convocation at Albany, said: "It requires little familiarity with students to recognize that they not only regard the athlete or the

man of social prominence as a far more promising personality than the high scholar, but that rank itself is in their minds little or no indication whatever of the qualities that make for success in life. This feeling seems to have been progressive, as is shown by the very words used to indicate the student who works hard. A generation ago he was called a 'grind,' but now he is often referred to as a 'greasy grind,' the adjective, of course, being used to denote contempt. In fact, it may be doubted whether the respect for scholarship has ever been so low in any institution of learning as it is in American colleges at the present day." We may listen also to the breezy catalogue of our neighbor, Professor Gayley. Speaking of the college student, he says: "What with so-called 'college activities,' by which he must prove his allegiance to the university, and social functions by which he must recreate his jaded soul, no margin is left for the one and only college activity—which is study. Class meetings, business meetings, committee meetings, editorial meetings, football rallies, vicarious athletics on the bleachers, garrulous athletics in dining room and parlor and on the porch, rehearsals of the glee club, rehearsals of the mandolin club and of the banjo, rehearsals for dramatics, college dances and class banquets, fraternity dances and suppers, preparations for the dances and banquets, more committees for the preparations; a running up and down the campus for ephemeral items for ephemeral articles in ephemeral papers, a soliciting of advertisements, a running up and down for subscriptions to the dances and the dinners and the papers and the clubs; a running up and down in college politics, making tickets, pulling wires, adjusting combinations, canvassing for votes—canvassing the girls for votes, spending hours at sorority houses for votes—spending hours at sorority houses for sentiment; talking rubbish unceasingly, thinking rubbish, revamping rubbish—rubbish about high junks, rubbish about low, rubbish about rallies, rubbish about pseudo-civic honor, rubbish about girls;—what margin of leisure is left for the one activity of the college, which is study?"

According to the Briggs report of 1904 Harvard students averaged twelve hours of class-room work and thirteen hours of outside work per week, or four hours per day only, devoted to the business of the undergraduate. Four years later the dean could still say: "That the present standard of work 'to pass' is low, the investigations of the Committee on Improving Instruction showed; undergraduates of to-day almost without exception frankly admit it. To obtain the necessary number of 'grades above D' ('the requisite number of C's,' is the common phrase) requires almost no steady, and only briefly concentrated, labor; nowhere except in a college would the work which produces 'the requisite number of C's,' the so-called satisfactory record, be tolerated from youths of equal age and endowment—nowhere else where young men

are supposed to be seriously at work is so low a standard in quality endured." In his report of the same year Dean Ferry, of Williams, says: "The spirit of the college is excellent in all respects save that of lack of seriousness toward the work of the class room. Could the undergraduate be made to believe that it is worth while to devote serious and uninterrupted effort to the study of the matter set before him in his college courses, the atmosphere of the college would leave little to be desired."

Mr. Birdseye counted twenty-seven distinct interests and occupations which engage the student in a modern university, outside of the work for which the university exists. "The teachers in our colleges," says Woodrow Wilson, "are men of learning and conceive it their duty to impart learning; but their pupils do not desire it; and the parents of their pupils do not desire it for them. . . . Many of the parents of our modern undergraduates will frankly tell you that what they want for their sons is not so much what they will get in the class room as something else, which they are at a loss to define, which they will get from the associations of college life." Speaking of amusements and athletic activities, he says: "Athletics has no competitor except these amusements and petty engrossments; they have no serious competitor except athletics. The scholar is not in the game. He keeps modestly to his class room and his study and must be looked up and asked questions if you would know what he is thinking about. . . . He deplores athletics and all the other absorbing and non-academic pursuits which he sees drawing the attention of his pupils . . . but he will not enter into competition with them."

In looking about for a scapegoat our critics have found the elective system the most handy. Those who hark back to the old humanistic college, like Princeton's ex-president, and those who recognize that the old has gone forever, like Mr. Flexner, seem to unite on this point. The elective system does well enough for the seriously minded. What does it do for his brother, of opposite inclination? asks Mr. Flexner. "It simply furnishes him an abundant opportunity to exercise a low ingenuity in picking his way to a degree with the least exertion, the least inconvenience in the way of hours, the least shock to the prejudices which function for him in place of ideas, tastes and convictions. He comes out at the spout as he went in at the hopper—except for the additional moral havoc wrought by four years of 'beating the game.'" Woodrow Wilson finds the evil of the elective system, not so much in the easy escape of the loafer as in the heterogeneity introduced, the dilution of the college atmosphere with professional and vocational aims. "It is notorious," he says, "how deep and how narrow the absorptions of the professional school are. . . . The work to be done in them is as exact, as definite, as exclusive as that of the office and the

shop. . . . It does not beget generous comradeship or any ardor of altruistic feeling such as the college begets. It does not contain that general air of the world of science and letters in which the mind seeks no special interest, but feels every intimate impulse of the spirit set free to think and observe and listen—listen to all the voices of the mind." Yet Princeton, of all American colleges freest of the taint of the elective system, had become, as described by ex-President Wilson himself, the pleasantest country club in America. Under the preceptorial system ex-President Wilson is now able to report Princeton as a place where undergraduates do a fair amount of good, intelligent work —" but," he adds, " nothing to get excited about "!

President Lowell notes that what has given these twenty-seven occupations—at least the absorbing ones—their fascination is the spirit of emulation which they foster and bring out to its fullest extent. The corrective therefor is to put the spirit of emulation into scholarship, to find the American equivalent to the Oxford and Cambridge dual pass-and-honor system. On this point Professor Münsterberg says: " If we can foster scholarship by an appeal to the spirit of rivalry, by all means let us use it. We may hope that as soon as better traditions have been formed, and higher opinions have been spread, the interest in the serious work will replace the motives of vanity. . . . Of course, no one can overlook some intrinsic difficulties in the way of such plans. No artificial premium can focus on the scholar that same amount of flattering interest and notoriety which the athletic achievement represents, in that little field, a performance which may be compared with the best. The scholarly work of the undergraduate, on the other hand, at its highest point necessarily remains nothing but a praiseworthy exercise, incomparable with the achievements of great scholars. The student football player may win a world's record; the student scholar in the best case may justify noble hopes, but his achievement will be surpassed by professional scholars every day."

In trying to domesticate the Oxford-Cambridge system Columbia has hit upon an interesting principle of segregation, described in the October *Educational Review*. A generation ago few students entered college without the definite desire to obtain a scholarly education. The student body was small and united in aim. To-day conditions are far otherwise. The spread of popular secondary education, the rapid increase and distribution of wealth, have placed a college education within the reach of those lacking both scholarly ambition and the traditions of culture, but to whom have come the opportunity and desire for social betterment. A boy of this sort is sent to college in order that in later life he may mingle freely and equally with college-bred men, that he may learn how to get along with his fellows, and by contact with them have his angularities removed. " It is quite idle," declares

Professor Mitchell, "to object that the college exists primarily for the production of scholarship and the training of scholars. . . . That has happened in collegiate education which is not unknown in commercial industry: the by-products have been discovered to possess unsuspected values, and in the wide-spread popular demand for them a profound change has been wrought in the college clientèle and in the needs which the colleges are called upon to meet. By a very slight and entirely logical extension of the system of free election we could let each take, for an appropriate fee, whatever he might desire of the goods the college had to offer." This deduction Professor Mitchell rejects because "on every side the system of free election has failed and broken into chaos precisely because the college is not a commercial enterprise." "Yet it is equally futile and ridiculous to attempt to make scholars of those who have no scholarly aptitude or ambition." Both kinds, however, may find their satisfaction in the same college, though not, he thinks, in the same classes. For the one class Columbia will provide scholarly training; for the other, something different. In Mr. Dooley's college, when the applicant for admission arrives, "th' prisidint takes him into a Turkish room, gives him a cigareet, an' says: 'Me dear boy, what special branch iv learnin' wud ye like to have studied f'r ye be our compitint professors?'" The Columbia president will not do this; but Columbia's enforced regimen for by-product majors will at least eschew the "futile and ridiculous" attempt to impose scholarship upon them.

I am frank to say that if the analyses represent the case at all fairly, the remedies seem inadequate. The elective system, for example, is a manifestation on the academic side of a transformation which has covered the whole range of college activity. Many causes have contributed to this result. The quickening principle was the German university ideal carried over to the American college by pioneers in that great procession of American youth who have sought the stimulus of German scholarship. Coincident with this has been the development of secondary education and the postponement of the period of college training. When the entering age was pushed up from twelve and thirteen to sixteen, eighteen, and even higher, a change in discipline was necessary. The multiplication of subjects of study made some sort of selection inevitable. If Harvard were to schedule but seventeen courses the elective system could be abandoned—for seventeen courses constitute a four years' program; whereas, if all the courses now offered were prescribed for graduation it would take the student more than seventy years to earn his degree. Of sheer necessity some freedom of choice must be conceded; and the invitation to the student to share in the selective process has been the most clarifying principle in modern higher education. The system has grown because it has worked. The

supplanting of the old self-improvement, or culture, theory by the German ideal of scholarship gave a tremendous impulse to serious college work. And with serious college work in hand, both the old paternalism and the childishness of the schoolboy college must necessarily slough off. "I will not ask you to be true to us," President White said at the opening of Cornell University in 1868. "I will ask you to be true to yourselves. In Heaven's name be men! Is it not time that some poor student traditions be supplanted by better? You are not here to be made; you are here to make yourselves. You are not here to hang upon a university; you are here to help build a university. This is no place for children's tricks and toys, for exploits which only excite the wonderment of boarding-school misses. You are here to begin a man's work in the greatest time and land the world has yet known." Cornell students responded to this appeal, and so did students the country over to similar appeals. Throwing dead cats through class room windows, locking professors in their rooms, muffling college bells, levitating domestic animals to third-floor chapels, and like customs, though they died hard, actually died. Definiteness of purpose was given to college study. The new subjects, with their fresh and unexplored fields, absorbed the student and gave him a seriousness his predecessor had lacked. A manlier attitude prevailed. Co-education began to arrive; and in all the state universities particularly, the presence of a body of serious-minded young women did much to elevate the atmosphere of college life. The superfluous energies of youth heretofore wasted in boyish tricks and worse turned to athletic sports, and to developing, one after the other, the twenty-seven activities Mr. Birdseye has noted. The testimony to the improvement in manners and morals within the student body is overwhelming. Petty regulations and rules of conduct atrophied and dropped off. College students began to be regarded and to feel as men and women, with responsibility for their own conduct—to the profit of all and to the immense relief of college authorities.

The flowering period of this cycle may be roughly fixed as the twenty-five years from 1870 to 1895. All went well so long as the impulse set free by the liberalizing of the college curriculum lasted, and while the college constituency was essentially homogeneous. In the later years certain vital changes were taking place, partly as the result of these very movements, partly from influences outside the college. Wealth and luxury became widely diffused. The schools multiplied and were free, and the opportunity of school and college came without effort. Going to college became part of the ordinary routine of a boy's and girl's life. With youths that were earnest there came also to college doors troops of the unearnest. The twenty-seven student activities became more and more engrossing. Within the college boundaries

there has grown up a rival institution, with antagonistic aims and ideals, to which the student body gives first allegiance.

If the college faces this new situation rather helplessly, as Mr. Flexner affirms, it is because analogy has here played its old trick. As a matter of fact, absolute election of studies by the student has nowhere existed. But in the wider matters of conduct and in the question whether to study or not to study the college has drifted without any clear principle of action. College students were treated as men and women, with good results. Therefore they are men and women. Therefore whatever the results, they must be treated as men and women with the privileges and responsibilities of men and women. Whatever happens, the college can do nothing except in the sphere of moral influence. As Mr. Birdseye sees it, "substantially all direct control of the personal freedom of the students has been given up except in cases where their action becomes scandalous or they break the public law. . . . The absolute personal freedom, which in many instances is but another name for laxity, undoubtedly tends strongly and constantly to personal shiftlessness and laziness as well as to bad mental and moral habits. . . . With the freedom of their fraternity and club life and the absence of faculty and parental restraint, have come constant distractions from study in connection with a succession throughout the year of class, fraternity, and intercollegiate games of football, baseball, basketball, tennis, golf, chess; of rowing, track and athletic meets; of glee, mandolin and banjo and other musical and dramatic clubs or associations; of receptions and other social functions, of literary dailies, weeklies, monthlies and annuals; and even of intercollegiate debates. . . . In most colleges there has grown up a decidedly false atmosphere, which affects adversely the personal lives of a greater or less proportion of the students." "I know of no place," wrote the dean of a western university to Mr. Birdseye, "where so much fine material coming from the country and small towns has been ruined by a single half-year of idleness and extravagance. The worst elements of city, social and fraternity life seem to be those most eagerly grasped after and most incessantly followed."

Suppose we follow the course of an imaginary freshman at the composite college of our critics; one who is well prepared, with a sense of the importance of his undertaking, and unsophisticated. What he seeks the college has to offer: facilities, scholarly standards, inspiring teachers. It is not at all certain that he will reach his goal. In the first place the scholarly atmosphere is not very evident—to a freshman. For days, weeks even, before the opening old students have drifted in. They have not done this in order to consult the authorities the better to plan and prepare for the studies of the year. They have plans of their own. They are at starting the wheel within the wheel.

They are about the planning of courses in athletics, in dramatics, in rushing, in tubbing, in college traditions generally. They have their own uses for the incoming freshman class, and their own elaborate and trying admission requirements. They condescend to notice the faculty's college when it becomes necessary to take their protégés in tow and make a dead set against some assumed weak spot in the college's entrance defenses. Mostly, to the freshman's eye, there is a whir of automobiles, a rushing to and fro with excited conferences over innumerable projects which bear little relation to the ideals with which he set out from home. The conversation he hears is not of studies or ideals of study. The standards of conduct, of appreciation of priceless opportunity, are what might be expected of a generation brought up on the modern daily newspaper, with town and city environment, whose fathers will set them up in business when college days are over, and who will take with ill-grace and much contempt of regulations the little learning they can not avoid without risking the pleasures and excitements which chiefly mark their progress toward a learned degree. If the freshman is put wise early he learns to submit with as much composure as possible to whatever rough treatment of his own person the college world decrees as appropriate to his crude state of development: the college authorities not being in this game, either. If above the hubbub his ear catches the announcement of an address to the entering class by the president of the college on Thursday evening, he knows that is a signal for special activity on the part of his sophomore friends. Consequently he stays in his room—unless, perchance, constrained to come flying forth in unceremonious fashion. But if the meeting be advertised for midday he may hear, for a moment, an echo of those ideals and principles which had beckoned and fortified him as he made his decision for a college course. This impression, however, is quickly swallowed up in the whoop-er-up speeches and cheers in behalf of college activities, in which the faculty seemingly participates with equal abandon. On registration day, for a brief space the college once more seems to hold sway; then it and its ideals fade into dim distance, while the real, absorbing college of student life resumes the scepter. When classes begin he follows instinctively a habit not yet outgrown, and essays to enroll with his instructors. But the freshman who had been something of a leader in his home school, who was thought to have learned a measure of self-reliance, who had even filled a position of responsibility in a very real experiment in self-government, now finds that he has by no means learned his place. While the academic sideshow of lectures and recitations is getting itself started in halting fashion, the freshman is in the fierce struggle and joy of real college life. As free of conventional wrappings as nature made him, he is paraded and tubbed in open daylight around faculty lawns and by campus

houses, and whiles away the forenoon in stunts which teach him his place some more and further his initiation into that innermost, sacredest circle, the knights of the college tradition. Since nothing can be done unless you get student sentiment behind it, the faculty sits in helpless inactivity; or, if the emotions are much stirred, rushes to its laboratories and attempts to think out some serum which will work upon the student mind and permit it to look with favor upon the studies of the college curriculum!

At last, it may be, the freshman is started in his studies. But attending classes and studying lessons is not as he had pictured it. The men whose names and imposing academic biographies had awed him from the pages of the college catalogue he must now learn to look at from the angle of his sophisticated companions. This one, frankly, is a chump; this other can be counted on to do the fair thing and not flunk a fellow; that one will be down on you anyhow. One is to be worked in one way; another, in another way. In this class you can safely cut as much as you like; in this other it is necessary to look after answering roll call. The main object is to keep from flunking out; for as yet absolute immunity has not been achieved, and real college life is too pleasurable to be hazarded too far. Getting something from the course is at least secondary. Getting the credit at present seems necessary, and, when hard pressed, one's wits need to be well sharpened. Why should one be too scrupulous, since it is only the book account that matters? Bluffing runs naturally into something more effective, and the freshman sees the game of cheating going on almost as a matter of course. Sometimes the instructor seems to him to be aware of the game, but too embarrassed to call for the cards; can not afford, in fact, to become unpopular, for may not the instructor's comfort, not to say his standing in the college, depend on the good will of the student? Once in a while the committee—blankety symbol of all that is hateful in an otherwise lovely environment—the committee connects with some luckless offender, who, bruised and bewildered, presently finds himself at the edge of the campus. All of which would be tragic, were it not so grotesque, for but a single head has been hit out of a multitude just below the line of breastworks. More and more absorbing are the activities of the college of student life; more and more the faculty's college and its obtrusive exercises become an incubus, more and more its occasional interferences become irritating and objects of student wrath. Dissipation masks as good fellowship. The grosser temptations lose horns and hoof. The freshman himself may be nor athlete, nor actor, nor editor, nor society devotee. But he learns to be vicariously active in all these pursuits; in an atmosphere of hazing, shamming, bleachering, beating the game, his whole moral and intellectual structure suffers irreparable shock.

Let us hasten away from this impossible college and come back for a brief space to the real institution, in which nevertheless some portion of this virus is at work. And first, it is safe to say that the day is not to be saved by a return to fixed programs of study made out of faculty piecings. Nor can Woodrow Wilson, or his successors, succeed in drawing off from the great mass of undergraduates the saving remnant foreordained to be separated for four years from all training that bears upon a special task—attractive as that ideal may be. Nor will President Hadley's ideal—"where a student learns things that he is *not* going to use in after life by methods that he *is* going to use"—ever again dominate the college. President Wilson found the work of the professional school "as exact, as definite, as exclusive as that of the office and the shop." The college can stand a large infusion of this ideal. Columbia's plan of providing an academic annex for majors in dullness, athletics and social functions seems none too promising. The junior college, and other compartment arrangements, useful perhaps as administrative makeshifts, are futile as attempts to segregate differing ideals of education.

In turning to greater administrative efficiency as a remedy, one can not but sympathize with the gentle plaint of Professor Showerman: "The professor thought of the administration of his college—of all the regents, registrars, clerks, secretaries, committees, and advisers, of all the printing and writing and classifying and pigeonholing, of all the roll-calling and quizzing and examination. What was all this marvellous system for? Why, simply this: in order that young men and women who came to college to get an education might be prevented from avoiding the very thing they came for!" Humiliating as the admission may be, that is about what it has come to. Of regents and registrars and pigeonholing and classifying we have perhaps a sufficiency. But of that concern for what Mr. Birdseye calls the student life department—ninety per cent. of the student's actual time—there is, alas, not a sufficiency.

Professor Barrows, who frankly abandons the undergraduate college as a period of serious intellectual effort, would still think of it as a moral opportunity—not for courses in ethics and formal moral teaching, I take it, but that by some process or other these bright, alert girls and boys might be enough arrested in their absorbing play to see, in the scholarly atmosphere shed from above, in the quiet ideals of the cloister, in generous comradeship with generous comrades, a moral quality and beauty that should win their allegiance and emulation. As a matter of fact, there has been too much reliance on the theory that somehow, through the mysterious processes of providence, just spending four years in college is in itself a saving and redeeming grace; that somehow shamming, and dissipation, and

moral lapse in college do not count in later life—since these also are exercise and training in the rights and responsibilities of manhood and womanhood. "One way to deal with these strange, excited, inexperienced and intensely human things called freshmen," says Dean Briggs, of Harvard, "is to let them flounder till they drown or swim; and this way has been advocated by men who have no sons of their own. It is delightfully simple, if we can only shut eye and ear and heart and conscience; and it has a kind of plausibility in the examples of men who through rough usage have achieved strong character. 'The objection,' as the master of a great school said the other day, 'is the waste; and,' he added, 'it is such an awful thing to waste human life!'"

A great mob of boys and girls are thronging the entrances of our colleges and universities. All need, most are entitled to, training; but not all are fitted and adapted to the college. Some ought to be in the shops and marts and homes acquiring discipline by contact with hard realities. Some are morally tainted and impervious to intellectual appeal. The mass is plastic and possible of development into capable, self-reliant citizenship. If the college can not find out these facts, who can? If the college can not rid itself of the unworthy, who is to do it? If the college can not make its standards dominate the college world, how can its work become effective? Up against these problems, the college must plead guilty to the charge of carelessness and ineffectiveness. In a situation where youths are on the way to manhood and womanhood, but not yet arrived, where standards are necessarily blurred and confused, the college has been more or less helpless, because it has not squarely faced the problems involved. It must be said again, the college can not go back into the old boarding-school chrysalis. Athletics, amusements, student activities, exercise of responsibility, were all welcomed into the college as aids to normal living, as making student life more wholesome. And so they were, and did. Paradoxical as it may seem, these are not yet widely enough diffused. We have come to our present plight because the college has had no consistent conception of its function in these matters. Harvard has retained the genial loafer for the possible good that might come "from contact between his back and the bricks of the college." But what about the contagion of his presence in a place where sound standards have to struggle to keep even a foothold? Other institutions have sought to rigidly exclude those who did not measure up to a fixed standard, though by a rough surgery that has sometimes seemed to treat measles and appendicitis pretty much alike. "It is comparatively simple," says Mr. Flexner, "to extirpate those who appear to be the weaker brethren; but it is not a whit more intelligent than to pull every aching tooth." Yet the aching tooth needs attention, and it must come to pulling at last, if nothing else is done.

Again, faculties are adjured to become acquainted with their students and to pay them social attentions. Excellent advice—usually where it is not needed! Occasions may not be forced. Social relations spring normally out of other relations. Instructors may rightly be reminded of responsibility and duty, but the up-to-date college, as Mr. Birdseye would phrase it, can not rely on untrained, voluntary service where training and unremitting attention are needed. Nor can the college turn to its dean or adviser and demand of him the physical impossibility of knowing every student and his particular problems and needs.

We may look hopefully to the preceptorial experiment of Princeton; as also upon the system of advisers which California and other institutions are developing with a view to giving the stumbling freshman the guidance he needs, and to saving as much material as possible from the college scrap-heap. There is promise also in the serum treatment of President Lowell, and one may reasonably expect the academic doctors, in the end, to produce a really valuable compound.

Yet these are only palliatives. The effective solution of the problem —the relation of student activities to university standards—is so simple that I hesitate to mention it. *It is that the college take charge of its own affairs.* Through these later years alma mater has been piling up her equipment, employing more and more professors, proclaiming her wares, absorbed in the task of growing. With some uneasiness, but with affected unconcern, she has seen growing up over against her own growth this monstrous structure of student activities, this artificial world of student life encased in traditions too sacred to be scrutinized and presided over by that stuffed goddess of liberty known as college spirit. Remembering that she once relieved herself of all *in loco parentis* functions and that all her students are men and women, alma mater has walked gingerly around this mountain and tried her level best to fit into the place assigned her. It is alma mater who has failed to notice the aching tooth or connived to conceal its existence from the doctors of the scholarship committee. It is alma mater who has permitted athletics and dramatics and the social whirls and editorialing and the rest of the twenty-seven activities to go beyond the limits of safety and sanity. It is alma mater who can not bear the responsibility of dropping men from college, who, obsessed with the idea that goodness is not created by legislation, thinks only of serums that may influence student sentiment or grasps at Columbia's peptonized diet as a means of providing degrees for those quite divorced from college study.

Alma mater's helpless concern recalls Mrs. Stetson-Gilman's encounter with the obstacle. Climbing up the mountain one day, she finds a prejudice blocking the path, cutting off the view, and absolutely refusing to move. She makes polite request, she argues, she scolds, she implores—all of no avail.

So I sat before him helpless,
  In an ecstacy of woe;
The mountain mists were rising fast,
  The sun was sinking slow—
When a sudden inspiration came,
  As sudden winds do blow.

I took my hat, I took my stick,
  My load I settled fair,
I approached that awful incubus
  With an absent-minded air—
And I walked directly through him,
  As if he wasn't there.

Actually the only reason why these twenty-seven activities do not stand in their proper, subordinate place—are not at once put where they belong—is the inconstant will of alma mater.

When, however, I said that the remedy was simple, I did not mean that it could be applied any how, any way. The means deserve careful thought and the exercise of such good sense as colleges may reasonably be supposed to command. But the main point is the will and determination of alma mater to have, and to have respected, standards of undergraduate conduct and achievement. In the face of such determination the loftiest structure buttressed by college tradition is a mere house of cards. Happily the mind of youth is plastic, and the hoariest college custom may on occasion be treated exactly as if it wasn't there. Certain qualities of heart and mind, with generous effort to improve opportunity, are minimum qualifications for membership in a college. The college has the duty and the authority—may it also have the courage—to set up and maintain standards which will justify indeed, and increasingly, democracy's faith in education.

THE PSYCHOLOGY OF MENTAL DEFICIENCY

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Come wander with me . . .
Into regions yet untrod,
And read what is still unread
In the manuscript of God.

THIS thought, which a few generations ago was uppermost in the mind of the great Agassiz when making his geological explorations, is to-day finding one form of expression in the scientific laboratory for psychological research at Vineland, N. J., where investigations are being made on the causes and conditions of human degeneration and mental deficiency. More vigorously to-day than ever before in the history of civilization, social, educational and psychological investigations are being carried into all phases of life with its misery, happiness and usefulness. Associations for charities, children's aid societies, guilds, juvenile courts and public school authorities, are asking the psychologists and physicians what can be done with these unfortunate people, the mental defectives, who are contaminating society by their presence, absorbing the time and thought that should be devoted to normal children, and later filling the almshouses, charitable institutions and prisons with illegitimate and irresponsible offspring.

The psychologist who analyzes, classifies, describes and explains mental phenomena is beginning to work effectively on the insane, the criminal and the defective. From a psychological standpoint, the border line between dull, backward and retarded children and those mentally defective, lies in a difficult and unexplained region. The inadequate knowledge of mental capacities and the desirability of accurately expressing the relative educational values of such capacities makes the field a most fertile one for research. With others, Ayres and Gulick have been studying the "laggards of our schools" for the Russell Sage Foundation, and Witmer, a pioneer in the field, has established the *Psychological Clinic* for the study of the normal development of every child. What of truly subnormal and mentally deficient children?

The study of mentally defective children began in 1797 when some French soldiers found "the wild boy of Aveyron" in a forest and had him taken to Dr. Pinel, of Paris, for examination. Pinel pronounced him incurable, which caused the publication of a pamphlet three years later by Itard, "De L'education d'un Homme Sauvage." This was the first important contribution to the literature of the subject; the second

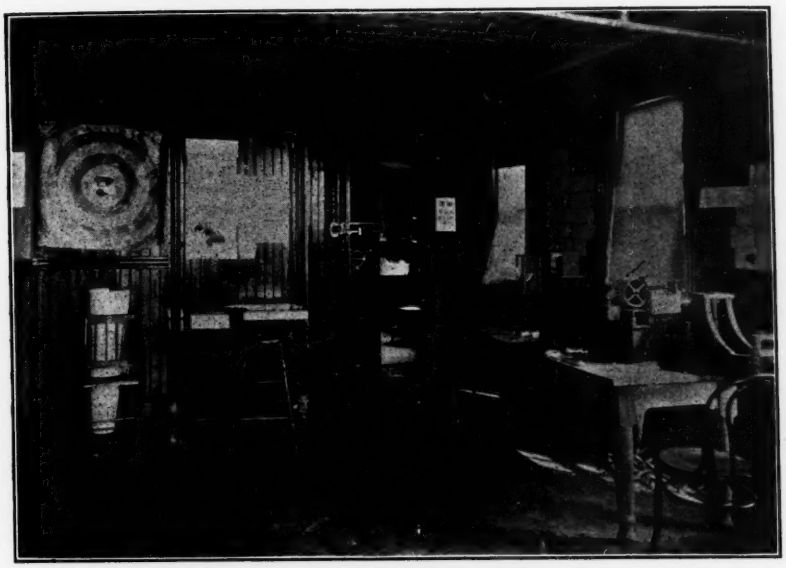


FIG. 1. A CORNER OF THE PSYCHOLOGICAL LABORATORY WHERE DR. GODDARD CONDUCTS HIS EXPERIMENTS. There are shown an ergograph, a chronoscope, which measures intervals of time to one thousandth of a second, a dark room for photographic work, an automotograph for recording involuntary movements of hand and arm, a target for testing precision in motor control, etc.

was from one of Itard's pupils, Seguin, who, in 1846, published his valuable work on the physiological treatment of mental defectives. About the middle of the last century, institutions for the care of defectives began to be organized throughout the world, and in 1904 Germany had 24, Sweden 33, England 12 and the United States 30 such homes. At the present time twenty-six of our states have a sum total of 25,000 children in institutions for feeble minded. The Vineland institution, in New Jersey, is one of the most progressive, and the psychological movement for which it stands is rapidly growing in importance and has many followers throughout this country and in some sections of Europe and Canada.

The best studies of the mentally feeble and defective have been made by Itard, Seguin, Howe, Powell, Ireland, Shuttleworth, Tredgold and Barr; among the psychologists who are formulating and trying out individual tests and finding methods of making mental diagnoses are Binet, Simon, De Sanctis, Meumann, Stern, Norsworthy, Thorndike, Goddard, Witmer, Huey, Whipple, MacMillan, Wallin and others; among physicians working in this field are Krenberger, Fernald, Wylie and Healy. One of the places where this study is being most successfully carried out is at Vineland, which has exceptional opportunities for research work because the institution is under private management as well as under state patronage, and it was here a psychological laboratory was founded in 1906, which was the first to be

permanently established in an institution for the care of mental defectives. The field is new and full of promise and the movement is rapidly growing in value and influences. This institution has comparatively few children (390 in all) and many of these come from wealthy families whose ancestry is known or from families who have lived in New Jersey for several generations. There are few communities of such stable population and so much inter-family marriage.

Institutional life and training is inferior, most of us will agree, to that of even a mediocre or low-grade home, but there are at least two groups of individuals who are exceptions to this general rule, the feeble minded and the insane. Both are *par excellence* individuals of state concern and state protection because they are incapable of self-direction, self-control or self-support. The defectives, who are by-products of unfinished humanity, belong in institutions where they may be cared for, made happy and to some extent useful, and where they may be studied for the betterment of civilization.

Lines of Investigation at Vineland

Dr. H. H. Goddard, Superintendent Johnstone and their field workers, are spending much time at present on the problem of *eugenics* —study of heredity. The home of each inmate has been carefully canvassed in order to get data which may throw light on the problem of heredity. What has been the result? Three concrete cases will suffice to indicate general tendencies.

1. An alcoholic insane paternal grandfather, a tuberculous cancerous maternal grandmother, imbecile mother with feeble-minded sister married to imbecile father. Result: Five feeble-minded children, one dead, one in custody, all the rest at large.

2. An insane father, a feeble-minded mother, seven children all mentally deficient; one in proper custody, one married, three in almshouse with mother.

3. A feeble-minded paternal grandmother, a neurotic maternal grandfather, an alcoholic father, a neurotic mother with a "queer" sister; ten children, eight feeble-minded children, two uncertain; one of this family in proper custody.

All of the children indicated "in custody" are at Vineland.

Proper care of the feeble-minded and epileptics would prevent this dangerous class from running at large and would help to solve the fundamental problem of the causes of mental deficiency (Figs. 2 and 3).

What are the controlling conditions of heredity? What are the results? The accompanying heredity charts which have been marked out with great care indicate controlling tendencies and suggest the question, Is Mendel's Law of Heredity, which has been proved for plants and animals, applicable to human beings? This is another important

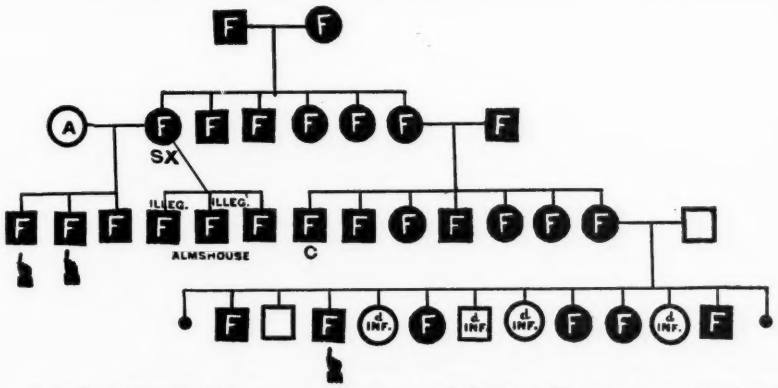


FIG. 2. HEREDITY CHART. Devised by Dr. Goddard, of Vineland, recently adopted by the American Association for Study of Feeble-minded and the American Institute of Criminal Law and Criminology and also used by Dr. Wm. Healy in his work in the Juvenile Psychopathic Institute of Chicago. This chart gives in graphic form the hereditary status of some cases at Vineland, N. J. Square = males; circle = females; clear square or circle means no data; *F*, feeble-minded; *A*, alcoholic; *T*, tuberculosis; *N*, normal; *C*, criminal; *Sx*, grave sexual offender; *d.inf.* means died in infancy; small black dot means miscarriage. Hand points to the child that is in the Vineland institution.

At the present writing three hundred and nineteen members of this family have been traced, one hundred and nineteen are feeble-minded and only forty-two are known to be normal.

problem being pursued. Dr. C. B. Davenport, who is the best authority in this country on eugenics, writes in a paper, soon to go to press, as follows:

APPLICATION OF MENDEL'S LAW TO HUMAN HEREDITY

For our purpose Mendel's law may be regarded as consisting of three principles. First, the principle of the unit characters of inheritable unit, each of which is, in accordance with the second principle, transmitted through the germ by a representative called a determiner. The third principle is that when the germ cells of both parents carry a determiner of a character the fertilized egg and the embryo derived from it have the determiner of the character double or

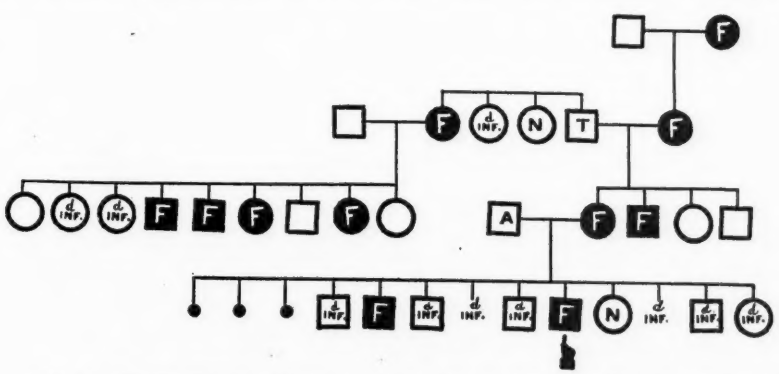


FIG. 3. THESE CHARTS ILLUSTRATE ONE TENDENCY IN THE THREE CASES JUST CITED, *i. e.*, mentally defective parents are very prolific. A very careful study made by Dr. Tredgold in England revealed the fact that sixteen mentally defective women working as mill hands had given birth among them to one hundred and sixteen children.

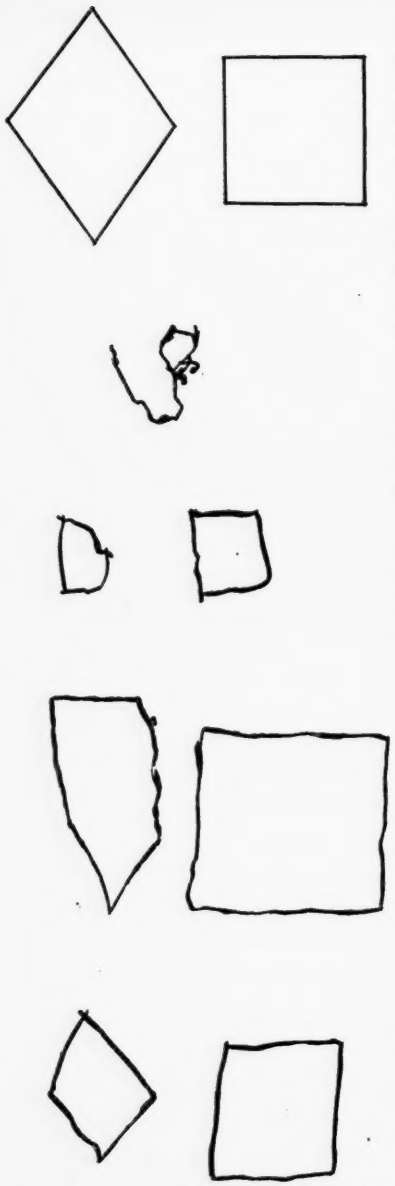


FIG. 4. DRAWING TEST. The upper drawing when reproduced by children of different ages indicates their mental development. The first copy shown, drawn by a white female aged eleven years, indicates a mental development of four years; the second, by a white female aged sixteen years, a development of five years; the third, by a white male aged eighteen years, a development of six years, and the fourth, by a white male aged nineteen years, a mental development of seven years. Reduced to one half.

duplex. When the germ cell of one parent only carries the determiner, this is simplex in the embryo. When neither parent carries the determiner the embryo is devoid of it. It follows that, if neither parent has a character none of their children can have it. If both parents have the character in question simplex, one fourth of their children will be without it; one fourth will have the character duplex and half will have it simplex again.

During the past ten years the study of the characters of plants and animals has revealed the nearly universal validity of this law—and during the past two or three years it has been shown to apply to many human qualities.

The law appears clearest in this form—when both parents lack a unit character all of their offspring lack it. Illustrations of this law are seen in the case of brown iris pigment. In case both parents lack it (and have blue eyes), all of their children have blue eyes. In case both parents lack curved hair all of the children have straight hair; if both parents have flaxen hair, the children are all like them; if the parents are blonds, lacking abundant skin pigment, so are their children. If both parents are defective in mental development, being imbecile, their children are all defectives.

When one parent is defective and the other has the additional character the children will have the character; but, since they get it from one side of the house only, the character is apt to appear in a diluted condition. Thus it may be confidently expected that the children of an imbecile and a normal parent will not all be as mentally strong as the stronger parent because their mental development depends on a simplex determiner.

The committee of eugenics of the American Breeders' Association has established headquarters at Cold Spring Harbor in the vicinity of New York City. It desires first to assist in a propaganda for the study of pedigrees of the feeble-minded. It wishes to urge upon every training school the desirability of sup-

porting at least one field worker who shall visit the homes whence come defective pupils and determine the mental condition of other individuals of the same germ plasms as are united in the pupil question. The Vineland School has set a shining example of this work and has achieved striking results. These studies really ought to be carried on in every state, not merely to confirm the laws of heredity of imbecility but to determine the main blood lines of imbecility coursing through this country.

So far we have considered the causes of mental deficiency of hereditary origin. The causes in general may be grouped roughly under direct, which are due to heredity or disease, and indirect, due to sense defects and accidents. About 85 per cent. of the cases may be traced to conditions prior to birth, such as bad heredity, neurotic conditions, alcoholism and tuberculosis. Injuries at birth are at the present time rare and are responsible for not over 1 per cent., according to the best authoritories. The remainder may probably be counted for by accidents, infectious diseases, epilepsy, malnutrition, etc., after birth.

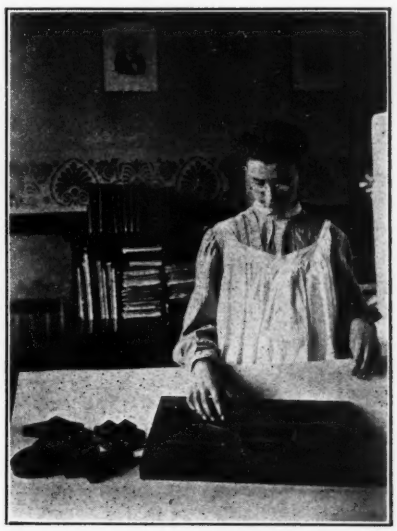


FIG. 5. PLACING BLOCKS IN THE FORM BOARD. With this form board, another type of test used in America, the child is required to place the ten blocks as rapidly as possible in their respective places. The experimenter observes and notes superfluous and jerky movements, the adoption of a method or system, *i. e.*, hunting the block to fit the space and *vice versa*, the ability to profit by experience when the test is repeated, the ability to increase a set pace of procedure, the degree of sustained attention, the span of motor control, and many other phases of mental expression. One bright boy of ten recently placed the blocks in their respective places in twelve seconds and a defective of nineteen required, after much urging and many vacillating and uncoordinated movements, seven minutes and eighteen seconds. Dr. Healy, psychopathologist for the Chicago Juvenile Court, has modified this type of form board by having the geometric forms a part of a puzzle picture which covers the face of the board.

This test alone throws much light on the mind of a child and may be used as a diagnostic test for children of varying grades of arrested mental ability.

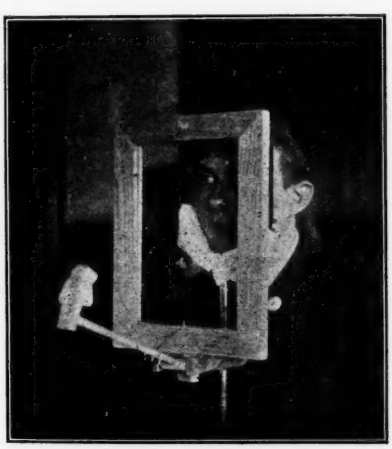


FIG. 6. A TEST FOR REFLEX ACTION AND MOTOR CONTROL. The apparatus as shown consists of a piece of glass in a frame which is struck by a rubber hammer. Low-grade defectives seldom wink.

Another line of activity in the Vineland research department has been the gathering of statistics on physical growth of defectives. A report of this work may be summed up as follows:

The lowest grades (idiots) are from two to four inches shorter and from five to fifteen pounds lighter than normal children of corresponding age.

The middle grades (imbeciles) are less than half this amount below normal, while the highest grades (morons) do not differ appreciably from normal children except that there is a tendency to become heavy.

Commenting on these results Dr. Goddard writes, "Normal children begin to grow fast at about eleven years. Among defectives this acceleration does not come until two years later, but when it does come it is a greater acceleration than in normals. This is not yet accounted for but it suggests that it may have an important bearing upon our treatment of school children at that critical age of eleven to fifteen."

The difficulty with these measurements, like all others on normal children, is the fact that they are based on one measurement of a large number of individuals and not on repeated measurements of the same individuals. An investigation soon to be published by the writer shows that two characteristics of growth of which Dr. Goddard has found true of deficient children, are characteristic of normal children as well. That is they naturally form two groups at adolescence, the short boys and girls beginning their rapid growth from one to two years later than the tall boys and girls, and there seems to be a direct correlation between rapid growth at adolescence and the advent of puberty for both boys and girls, the shorter ones maturing later than the tall ones.

Classification of Mentally Deficient Children

Dr. Howe, who is best known from his work with the blind, attempted to group all mentally deficient children under the headings "simpletons," "fools" and "idiots," but the most widely accepted classification to-day is that of Dr. Barr, of the Elwyn Training School, Pennsylvania, who classifies them as "feeble-minded," "imbeciles" and "idiots."

A new classification has recently been adopted by the American Association for the Study of the Feeble-minded. It is functional rather than physiological and is as follows:

Mental Age	Capabilities	Class	
Under one year,	Helpless.	Low	Idiot.
1 year,	Feeds self. Eats everything.	Middle	
2 years,	Eats discriminatingly.	High	
3 years,	No work. Plays little.	Low	Imbecile.
4 years,	Tries to help.		
5 years,	Only the simplest tasks.	Middle	
6 years,	Tasks of short duration. Washes dishes.		
7 years,	Little errands in house. Dusts.	High	

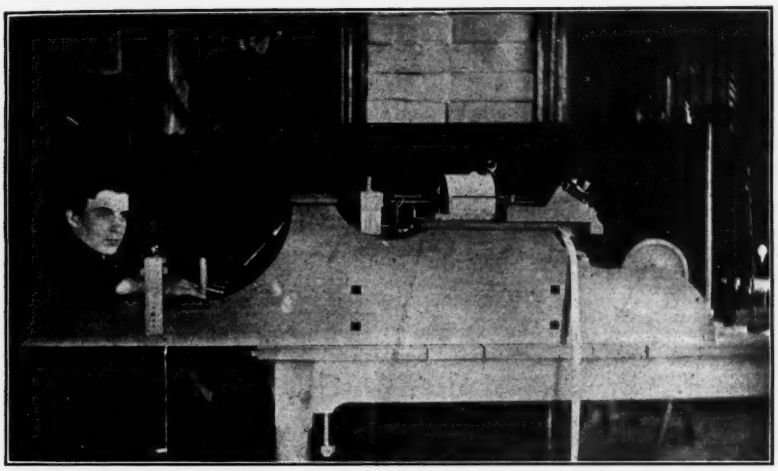
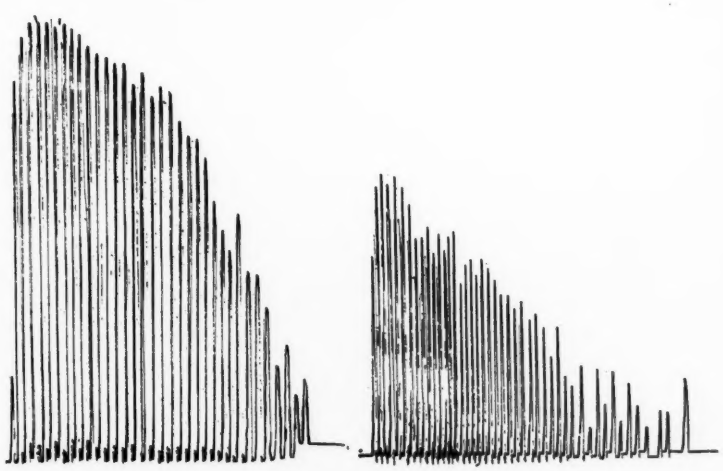


FIG. 7. AN EXPERIMENT IN ACTION WITH THE ERGOGRAPH.

Mental Age	Capabilities	Class	
8 years,	Errands. Light work. Makes beds.	Low	Moron.
9 years,	Heavier work. Scrubs, mends, lays bricks, cares for room with simple furniture.		
10 years,	Good institution helpers. Routine work.	Middle	
11 years,	Fairly complicated work with only occasional oversight.		
12 years,	Uses machinery. Cares for animals. No supervision. Can not plan.	High	



FIGS. 8 and 9. ERGOGRAMS. Records of a normal man and of a defective boy, the latter showing characteristic irregularities.

The ergograph was devised by Mosso, an Italian psychologist, and is used to measure muscular fatigue. A weight is lifted with one finger every alternate second until the muscle is tired out. Each lift is recorded on a vertical line and the sum total of lifts and lengths of lines are indicative of muscular action and voluntary control.

An idiot, according to this classification, can not reach a degree of mentality beyond that of a normal child of three years, an imbecile beyond seven and a moron beyond twelve. This has been determined by means of a series of tests.

Mental and Physical Tests

There have been several attempts during the past fifteen years to formulate a series of graded tests which will evaluate children's span of intelligence and measure mental defects by means of comparison with posited norms. Binet has been at work longest trying to formulate such tests and with some success and while the Vineland and Lincoln institutions are adopting the Binet and Simon tests for work with feeble-minded children, the University Elementary School, of the University of Chicago, and the Psychopathic Institute, of the Chicago Juvenile Court, are establishing norms for normal American children.

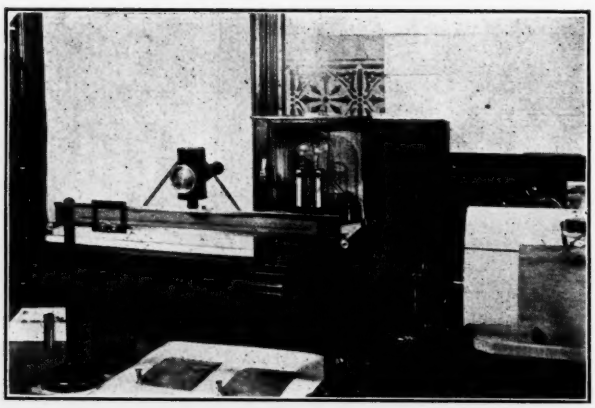


Fig. 10. Psychometer. The psychic galvanometer or psychometer, which is used to detect delicate physiological changes which accompany the emotional experiences of children. This apparatus is also used in psychological methods for detecting crime, although the nature of the phenomena giving rise to the galvanometric deflections is still an open question.

The Binet and Simon tests throw little light on the moral or physical nature of the child, and they do not allow for sense defects, which would naturally affect a child's standing, even though normal in other respects. The latest edition of these tests takes into account the age of the child, and eliminates almost entirely the factor of training by measuring what the child learns fortuitously. They thus form a "measuring scale for intelligence" and are of direct value and interest to all parents and teachers of normal as well as backward or defective children. The fifty-seven tests cover the period from three to twelve years, and if a child succeeds in the tests derived for his age, he is normal; if he can succeed only in the test devised for a child one year

younger, his development is arrested to the extent of one year, and similarly for two or three years. If he is unable to do the tests for more than three previous years, he is mentally defective and his mental age is determined by the tests which he can accomplish.

The test for a child of six years of age mentally is as follows: Shows right hand, left ear. Repeats sentences of 16 syllables. Distinguishes pretty from ugly or deformed faces, in pictures. Defines, in terms of use, the words table, chair, horse, mama. Performs three commissions given simultaneously. Knows age. Knows whether it is forenoon or afternoon.

FIG. 11. An apparatus devised by Dr. Goddard for testing the ability to recognize objects by the sense of touch (stereagnostic sense).

The tests for seven are: Notes omission of eyes, nose, mouth or arms, from portraits. States number of fingers on right hand, left hand, both hands. Copies written sentences, with pen, so they can be read. Draws diamond-shaped figures from copy (child of mentality of six years can not do it. See illustrations, Fig. 4.) Repeat five numbers in order, when heard once. Describe a picture shown. Counts 13 pennies, one by one.

FIG. 12. THE MAZE TEST FOR MOTOR CONTROL. Reduced to one half. A device first used at Columbia University for testing the ability to trace the white line in a given interval of time. Frequent contact with the sides indicates poor motor control. High-grade feeble-minded children usually make from 60 to 100 contacts. The tracing reproduced was made by an epileptic and contains 84 contacts.

Mentally defective children seldom reach the mentality of a normal child of twelve years, who can meet the following requirements. Rearranges shuffled words of eight-word sentences. Repeats seven numerals in order, when heard once. Names three words that rhyme with obey, in one minute. Repeats, with no errors, sentences of 26 syllables. Infers a fact from given circumstances which indicate the fact.

Three hundred and seventy-eight defectives at Vineland have been tested with the complete Binet tests with the following results:

Mental Age	Boys	Girls	Total
1	25	11	36
2	25	12	37
3	21	19	40
4	30	7	37
5	29	13	42
6	30	9	39
7	30	17	47
8	33	11	44
9	23	7	30
10	7	7	14
11	5		5
12	5	2	7
	263	115	378

The following photographs show types of tests, used for making mental diagnoses of children at Vineland, the Lincoln Institution in Illinois, the University of Chicago, the Chicago Juvenile Court, Columbia University, University of Pennsylvania, University of Washington, University of Texas, and similar institutions (Figs. 4 to 14).

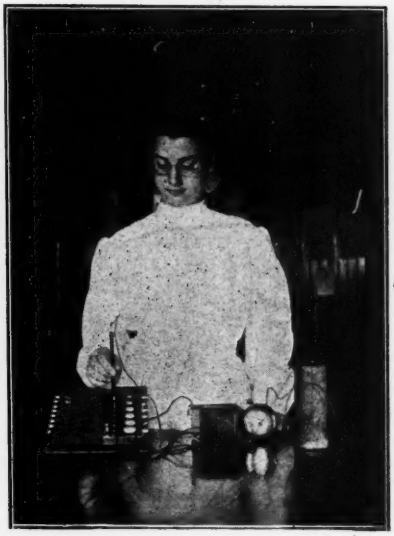
The foregoing tests and experiments show that mentally defective children offer excellent material for psychological investigation, since they are a more or less isolated group with quite definite boundaries and are dependent on others. They may be observed continuously during their lifetime, they are incapable of being stimulated or enthused by artificial reactions, they are not easily embarrassed or self-conscious; some of their mental processes are slowed down, others almost eliminated and some grossly exaggerated; their motor reactions are usually the direct result of their ideas with little inhibition, decision, choice or judgment, and may therefore be considered fairly safe criteria of the concomitant mental activities. The various stages of mental deficiency frequently parallel the stages of development of the normal mind and since the defective mind may remain for a lifetime at a given level, it may be studied in such a manner as to shed much light on the corresponding stages of the developing mind of the normal child, which is so fleeting in its passage to higher levels.

Finally: 1. Defectives are worthy of careful study for their own sake, for the welfare of society, and for the scientific insight they offer into the mental processes of normal children and the problem of education.

2. They offer, where their ancestry may be traced, the best material at present available for the study of human heredity on account of the pronounced deviations which may be traced.

3. They have so far contributed most to the scientific application of "mental and physical tests" which dominates contemporary tendencies in child psychology and its application to education.

4. Mental defectives present tremendous sociological difficulties in



FIGS. 13 and 14. PRECISION TESTS IN MOTOR CONTROL. The girl in the picture is a high-grade imbecile and is able to thread this large needle and touch the copper points with the stylus. A child of slightly lower grade could do neither.

the advancement of our present-day civilization and educational progress. As cure is impossible, the two chief sources of prevention suggested are to keep such people segregated in institutions and to prevent marriage. Other means may in extreme cases be justifiable; sometimes sterilization is found advisable, but popular opinion usually rebels against such measures.

JACOBUS HENRICUS VAN'T HOFF

By Professor HARRY C. JONES

JOHNS HOPKINS UNIVERSITY

THE death of Van't Hoff removes one of the leading men of science not only of this age, but of all time.

Born in Rotterdam in 1852, the son of a physician, he received his early training in the Realschule in Rotterdam and in the Polytechnikum in Delft. At twenty he had completed his work in the University of Leiden. He then studied under Kekulé in Bonn and Würtz in Paris, and obtained the Doctor's degree at Utrecht, at the age of twenty-two.

Van't Hoff, in 1876, was appointed privatdozent in physics in the veterinary college in Utrecht. In 1877 he was called to Amsterdam as lecturer in chemistry, and was appointed professor of chemistry in 1878, a position which he held until 1896, when he accepted a call to a chair created for him at Berlin. He held this chair and was also a member of the Berlin Academy of Sciences until his death on March 1, 1911.

Van't Hoff did three great things. His early work was with Mulder in Utrecht, Kekulé in Bonn and Würtz in Paris, and therefore, in organic chemistry. He raised and answered the question, what is the arrangement in three dimensions in space of the atoms in the simpler compounds of carbon? Henri had shown that the four hydrogen atoms in marsh gas (CH_4) all bear the same relation to the molecule. The geometrical configuration of this molecule follows of necessity from this fact. The only geometrical form in three dimensions in space fulfilling the condition of a central object surrounded symmetrically by four things of the same kind, is the regular tetrahedron. Thus arose the theory of the "tetrahedral carbon atom."

Some compounds of carbon rotate the beam of polarized light to the right, others to the left—are "optically active," as they are termed. Pasteur had pointed out that this is possible only in compounds in which there is some kind of asymmetry. Van't Hoff showed in what the asymmetry consisted. He showed that all optically active compounds of carbon then known contain a carbon atom in combination with four different atoms or groups, and the same holds true to-day. Such a carbon atom is known as an "asymmetric carbon atom," and thus arose the theory of the "asymmetric tetrahedral carbon atom,"

which has been the philosophy of organic chemistry for the past thirty-five years, and the guiding thought in practically all of the best work in organic chemistry from 1874 to the present time.

The second great work of Van't Hoff had also to do primarily with the chemistry of carbon. In 1867 the Norwegian physicist, Guldberg, and his son-in-law Waage, the chemist, both of Christiania, announced the law of the effect of mass or quantity on chemical reaction—the law of mass action. This was published in the "Announcements" of the University of Christiania, and very little attention was paid to it for some time. Guldberg and Waage applied their law to comparatively few reactions.

Van't Hoff, shortly after the publication of his brief paper of eleven pages in Dutch, on "The Arrangement of the Atoms in Space," took up experimentally the study of the velocities of chemical reactions and the conditions of chemical equilibria, from the standpoint of the law of mass action. He, his assistants and students, carried out an elaborate series of investigations in which the law of mass action was applied to a large number of chemical reactions, and shown to hold. The results of this work were published in French, under the French equivalent of "Studies in Chemical Dynamics." In this work the whole subject of chemical dynamics and chemical equilibrium was placed upon a scientific basis, and for the first time.

The third and greatest work of Van't Hoff had to with the relation between solutions and gases. Through his colleague—the botanist, De Vries, the attention of Van't Hoff was called to the osmotic pressure measurements that had been made by the botanist Wilhelm Pfeffer. A comparison of the results obtained by Pfeffer with the gas pressures exerted by gases containing the same number of gaseous molecules in a given volume that the solution contained dissolved molecules in the same volume, showed that the gas-pressure was exactly equal to the osmotic pressure—in a word, the laws of gas-pressure apply to the osmotic pressure of solutions.

Van't Hoff showed that the laws of gas-pressure apply to the osmotic pressure of solutions of non-electrolytes, *i. e.*, those substances whose aqueous solutions do not conduct the current. He also pointed out that the laws of gas-pressure do not apply to the osmotic pressure of a single electrolyte—a single acid, base or salt. Arrhenius explained the apparent discrepancy in the case of electrolytes by means of the theory of electrolytic dissociation, which says that acids, bases and salts in aqueous solution are broken down into charged parts or ions.

The question arises why is it so important to have shown that the laws of gas-pressure apply to the osmotic pressure of solutions? We know more about matter in the gaseous state than in any other state of aggregation. We can deal with gases from the standpoint of the

only exact branch of science—mathematical physics—and Van't Hoff showed that we can deal with solutions in the same manner.

This raises the further question why is it so important to have a satisfactory theory as to the nature of solutions? A moment's thought will furnish the answer. The whole science of chemistry is a branch of the science of solutions. Similarly, the biological sciences are dependent upon solution for their existence, and geology, in dealing both with the sedimentary and the igneous rocks, is vitally concerned with solution in the broader sense of that term. There are, then, few branches of natural science that are not dependent upon solution for their existence.

Van't Hoff made a number of other contributions to science, second in importance only to those named above. He told us what is meant by "Solid Solutions." His last work was an experimental study of the conditions under which the great salt beds at Stassfurth were laid down from a desiccating inland sea.

Van't Hoff published a number of books on physical chemistry but it would lead us too far here to discuss them in any detail.

The writer knew Van't Hoff in the relation of student to teacher. He was one of the most modest, frank, honest and unselfish of men. He lived to see his work properly understood and appreciated. He was elected a member of most of the learned societies and academies in the world. He was awarded the first Nobel prize in chemistry in 1901.

The name of Van't Hoff will undoubtedly go down in the history of science along with those of the very greatest—with Maxwell and Sir J. J. Thomson; with Laplace and Pasteur, and with Helmholtz and Lorentz.

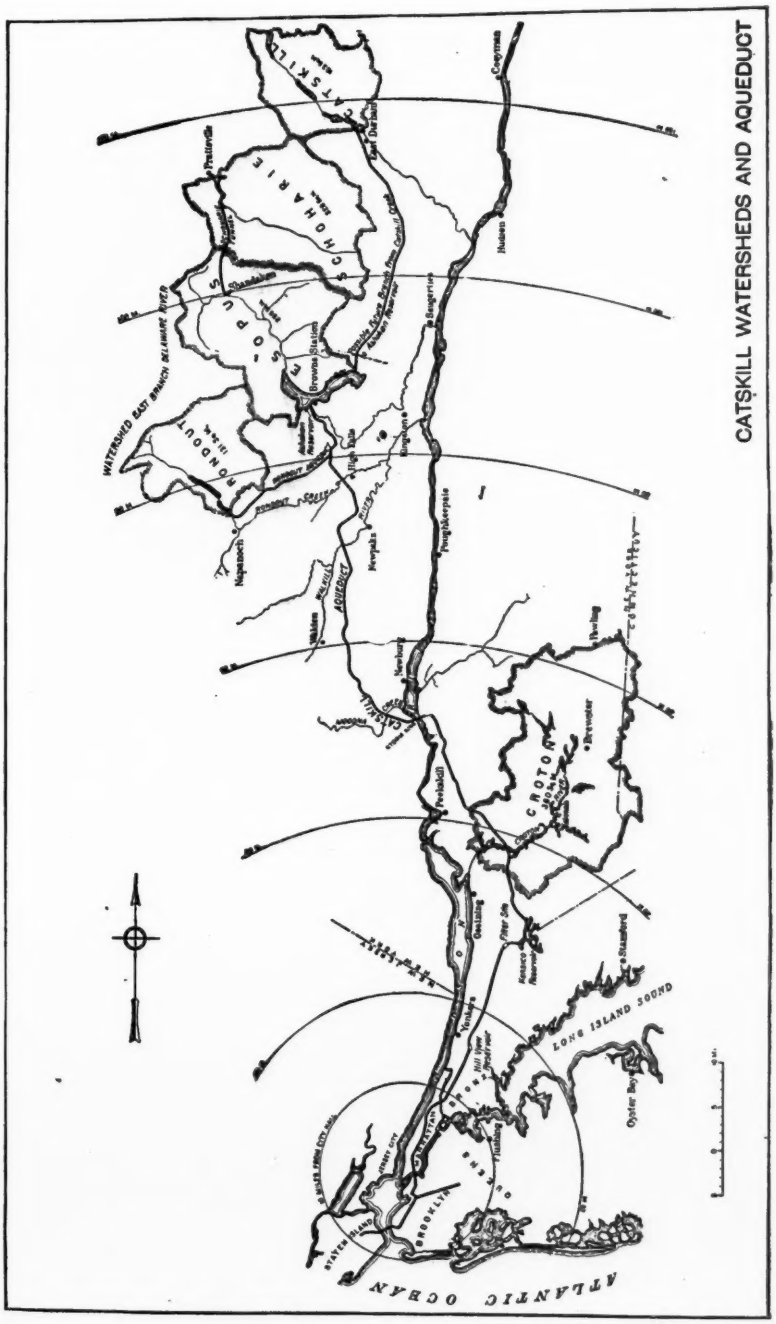
THE PROGRESS OF SCIENCE

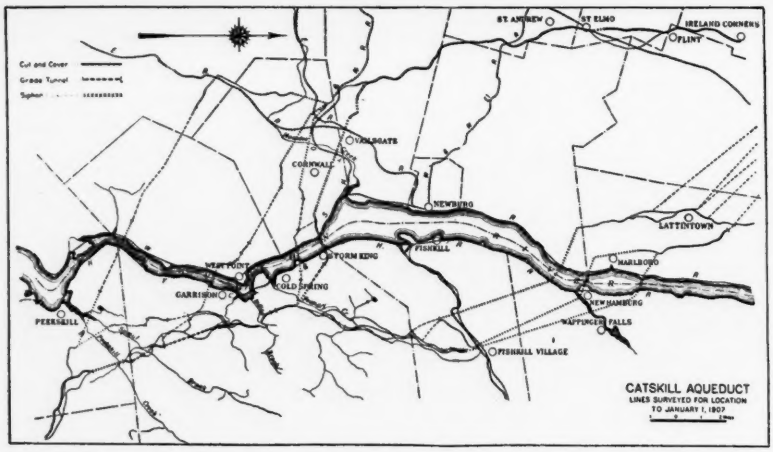
THE CATSKILL AQUEDUCT

THE supply of water for New York City is an engineering and economic problem of the greatest possible importance. The supply from the Croton watershed is at present just about equal to the consumption; if the rainfall during the present year should be small, there is danger lest there be an actual water famine in New York City, the harmful results of which would be almost incalculable. The consumption could be considerably lessened by requiring meters in each house measuring the amount of water used, and it would doubtless be desirable to introduce this system, though it would not give permanent relief. The average daily consumption of Croton water in New York City is over 350,000,000 gallons and the increasing population causes an annual increase of fifteen million gallons a day. Unless an interstate agreement could have been made by which water should have been obtained from Connecticut, the Catskill region is the only source that will give an adequate supply for a long period of years. The engineering problems of bringing the water a hundred miles from the Catskill Mountains are of great magnitude; the construction of the aqueduct is nearly equal to that of the Panama canal in difficulty and in cost.

The geology of the region and to a large extent the engineering problems are reviewed in a bulletin issued by the New York Education Department and prepared by Professor Charles P. Berkey, of Columbia University. The facts and illustrations for this note are taken from this report. The surface of the Ashokan reservoir in the Catskills will be 590 feet above the sea, and the High View reservoir within the limits of New York City will have an elevation of 295 feet. The length of the aqueduct between the two reservoirs will be approximately 92 miles and the main distributing conduit in

A VIEW OF THE CATSKILL MOUNTAINS, looking across the Beaverkill basin which is to form a part of Ashokan Reservoir.

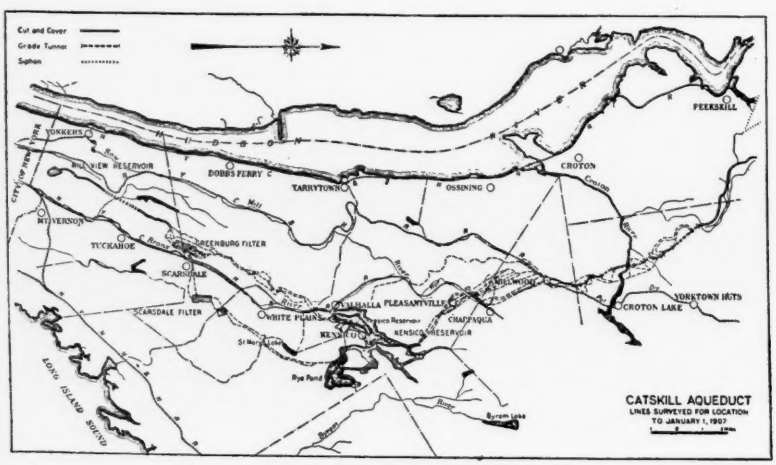

CATSKILL WATERSHEDS AND AQUEDUCT
ATLANTIC OCEAN
LONG ISLAND SOUND
CROTON
Croton Dam
Croton Lake
Kensico Reservoir
Hill View Reservoir
Jerome Park Reservoir
Yonkers
Mount Vernon
New Rochelle
Pelham
Port Chester
Rye
Harrison
White Plains
Scarsdale
Hastings
Dobbs Ferry
Tarrytown
Sing Sing
Ossining
Peekskill
Cortlandt
Verplanck
Haverstraw
Nyack
Piermont
Nanuet
Spring Valley
Suffern
Ramapo
Pompton
Paterson
Passaic
Newark
Jersey City
Hoboken
Bayonne
Elizabeth
Rahway
Perth Amboy
Staten Island
Brooklyn
Queens
Flushing
Whitestone
Long Island City
Astoria
Yonkers
Stamford
Greenwich
Oyster Bay
Babylon
Patchogue
Riverhead
Greenport
Sag Harbor
Montauk Point
Port Jervis
Middletown
Goshen
Warwick
Monroe
Chester
Greenwood Lake
Ringwood
Wanaque
Pompton Lakes
Boonton
Dover
Succasunna
Morristown
Chatham
Madison
Summit
Elizabeth
Rahway
Perth Amboy
Freehold
Asbury Park
Long Branch
Red Bank
Matawan
Keyport
Belmar
Point Pleasant
Toms River
Lakewood
Barnegat
Tuckerton
Atlantic City
Somers
Peekskill
Croton Falls
Brewster
Dover Plains
Pawling
Poughkeepsie
Hyde Park
Rhinebeck
Kingston
Saugerties
Catskill
Coxsackie
Athens
Hudson
Germantown
Rhinecliff
Tivoli
Red Hook
Rhinebeck
Millbrook
Pine Plains
Millerton
Amenia
Sharon
Salisbury
Lakeville
Canaan
Falls Village
Cornwall
Cornwall Bridge
Kent
New Milford
Danbury
Bethel
Redding
Ridgefield
Wilton
Norwalk
Westport
Fairfield
Bridgeport
Stratford
Milford
New Haven
Meriden
Wallingford
Cheshire
Waterbury
Naugatuck
Derby
Ansonia
Seymour
Oxford
Southbury
Woodbury
Roxbury
Bethlehem
Watertown
Thomaston
Torrington
Winsted
Colebrook
Norfolk
New Hartford
Barkhamsted
Riverton
Pleasant Valley
New Hartford
Canton
Simsbury
Avon
Farmington
Bristol
Plainville
New Britain
Berlin
Meriden
Middletown
Portland
East Hampton
Colchester
Hebron
Marlborough
Glastonbury
Rocky Hill
Wethersfield
Hartford
East Hartford
Manchester
Vernon
Rockville
Ellington
Tolland
Stafford
Willington
Ashford
Eastford
Pomfret
Putnam
Thompson
Killingly
Brooklyn
Woodstock
Union
Ashford
Willington
Tolland
Vernon
Rockville
Stafford
Somers
Enfield
Suffield
Windsor Locks
Windsor
Bloomfield
Simsbury
Granby
Barkhamsted
New Hartford
Winchester
Torrington
Litchfield
Morris
Bethlehem
Woodbury
Southbury
Oxford
Seymour
Ansonia
Derby
Shelton
Stratford
Fairfield
Westport
Norwalk
Wilton
Ridgefield
Redding
Bethel
Danbury
New Milford
Sharon
Salisbury
Lakeville
Canaan
Falls Village
Cornwall
Cornwall Bridge
Kent
Washington



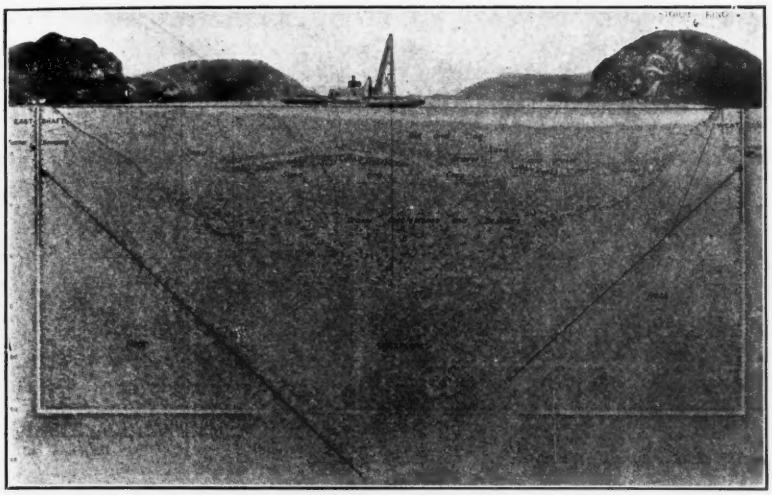
OUTLINE MAP SHOWING ALTERNATIVE LINES STUDIED AS POSSIBLE CROSSINGS OF THE HUDSON RIVER.

New York City will be eighteen miles long. The Ashokan reservoir is at a sufficient elevation to permit water to flow down to the Hill View reservoir, but a number of valleys and streams must be crossed, the most striking, from the point of view of the outsider at least, being the gorge of the Hudson River. More than two hundred borings were made at various points, and it was finally decided to construct the aqueduct under the Hudson between Storm King and Breakneck mountains at the north entrance to the Highlands.

It would be possible to bring the water in iron pipes through the mud and silt, as has been done in the case of the Pennsylvania Railway in New York City, but a tunnel through the rock will give great strength and permanence. The accompanying illustration shows the borings which have been made at Storm King, revealing the extraordinary depth of the Hudson gorge. It has been known through the maps of the U. S. Coast and Geodetic Survey that the Hudson River is continued by a submerged gorge more a hundred miles across the continental shelf to the deep sea. This gorge at its deepest part is 3,800 feet in depth, and must apparently have been formed



GENERAL LOCATION MAP OF THE SOUTHERN AQUEDUCT AND ASSOCIATED PARTS OF THE CATSKILL SUPPLY.



A COMPOSITE DIAGRAMMATIC CROSS SECTION OF THE HUDSON GORGE AT THE STORM KING CROSSING, showing the method of making the vertical borings, the direction of the first two inclined borings, the positions of the shafts and the extent of explorations. (Adapted from drawings of the Board of Water Supply.)

during an epoch of great continental elevation. The borings in the Highlands have been carried to a depth of 750 feet without reaching the bottom. This is more than twice as great a depth as has been found at any other point either above or below, though even at Pegg's Point and at New York City it is possible that there is a narrower gorge in the middle of the river. The great width and depth of this gorge must have been due to glacial erosion when a stream of ice was forced down from the wide bay that then existed north of the mountains. The syphon tunnel under the Hudson is only one of a number of great syphons and aqueducts that must be constructed between the Catskills and New York City. Owing to the present

CATHEDRAL GORGE, a postglacial entrenchment of Esopus Creek at the Tongore site. The preglacial gorge lies at the north side of the valley buried beneath 250 feet of drift. (Photograph by Board of Water Supply.)

need of the watershed, it is proposed to develop at first only the Esopus watershed by the construction of the great Ashokan dam at Olive Bridge and to carry the water to the present Croton system, the aqueducts of which are somewhat in excess of the Croton supply in dry years. It is hoped that this part of the undertaking may be completed within three years.

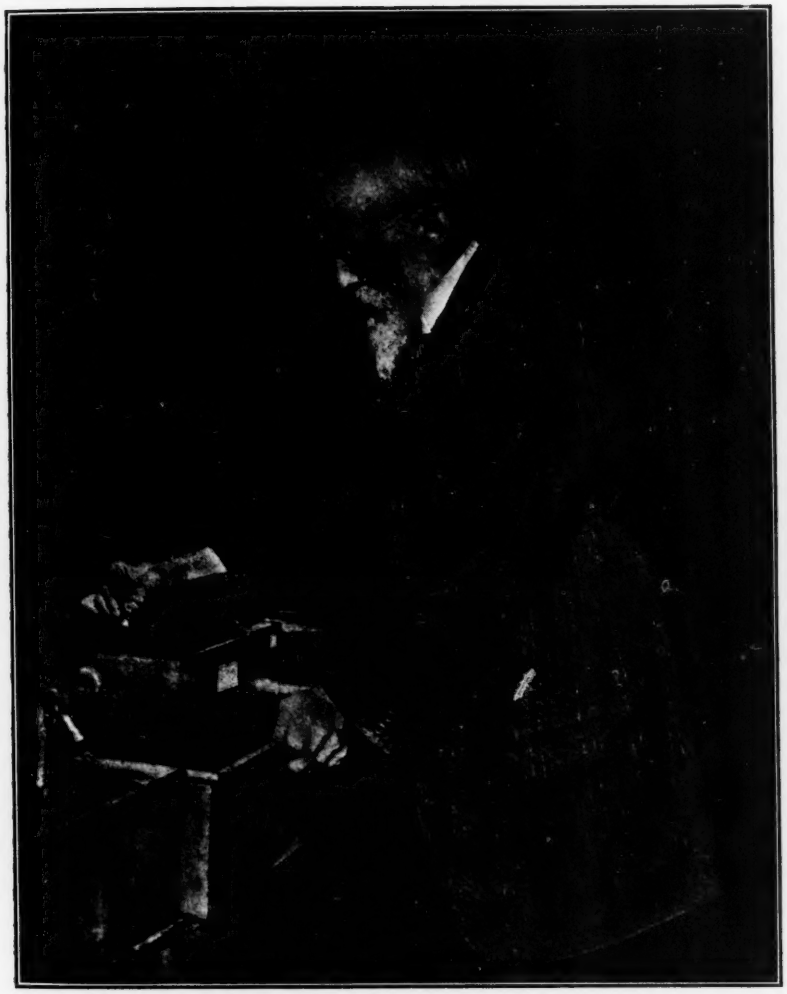
THE AMHERST IDEA

THE class of 1885 of Amherst College at its twenty-fifth reunion a year ago appointed a committee to present to the trustees an address on the future development of the college. It is an interesting fact that the alumni of a college should concern themselves with scholarship rather than with athletics, and the address is a document of such considerable moment that it has attracted wide attention. The committee signing the report points out that the conditions for a college such as Amherst have changed in the course of the past twenty-five years. The great universities, especially the state universities, take students from the high school and graduate them prepared for a technical career. A college such as Amherst can not compete with these institutions. According to the committee it has or should have other objects. It should demand a preparation not within the tendencies of the high schools, and give a course which postpones preparation for a profession. Amherst should retain, or return to, a liberal or classical education and confine its work to this. The committee makes to the trustees five definite propositions:

1. That the instruction given at Amherst College be a modified classical course.
2. That the degree of bachelor of science be abolished.
3. That the college adopt the deliberate policy of devoting all its means to the indefinite increase of teachers' salaries.
4. That the number of students attending the college be limited.
5. That entrance be permitted only by competitive examination.

The committee does not make clear just what a modified classical course should be. They say that all would agree that some knowledge of science is part of a liberal education and that no one would advocate the adoption of the unchanged classical course of fifty years ago. They also say that a classical education is a training in civics, the history of government, etc. The difficulty is that if students are to be thoroughly trained in Latin and Greek, they must specialize quite as much as students preparing for the professions. Now that we have admirable technological schools, it would apparently be desirable to have schools that would specialize to the same extent in the languages, on the one hand, and in history and political science, on the other. This is not because, as the committee argues, technical education teaches devices instead of principles, and is one of the causes of the increased excitability of American politics. This is little short of nonsense. But it would be desirable for one college to give a thorough classical education for the training of scholars in this direction and as a basis for work in literature, in law and in other professions. It is an advantage for men to enter on their professions with diverse training in order that they may specialize in different directions. Such a college should have a graduate department, which the Amherst committee apparently regards as superfluous, in order to maintain the scholarship both of its professors and of its students.

This, however, is presumably not at all what is wanted by the committee; it would let Amherst College give a liberal education on the lines, for example, advocated by President Lowell, teaching those things which a cultivated gentleman should know. If such an education is desirable there is much to be said for giving it at a small college rather than in a great university. If a college is limited to some three hundred students, it is possible for all the students to attend the same courses, to know each other and all the



Dr. Richard Hertwig

This portrait of the eminent zoologist of the University of Munich shows him at the age of sixty years, when a "Festschrift" has been prepared in his honor by his former students.

professors, and for the professors in turn to teach and know all the students, and to feel personally responsible for the work of the whole institution. It is, however, somewhat difficult to decide how the number of students shall be limited. According to the committee it should be done by competitive examinations. This, however, is a doubtful expedient, as the preparation for a competitive examination is not necessarily the best educational method, and young students who can pass such an examination with the highest grades are not always those who will be successful in their later work. It would apparently be a better plan to admit all promising students and to drop a considerable percentage at the close of the first year. Under these conditions students are likely to work well at the start, whereas if they pass a competitive examination of which they do not particularly approve they may feel that they deserve some relaxation. It would probably be desirable for Amherst to decrease the number of students by giving up the degree of B.S., unless the college is prepared to offer adequate courses in the natural and exact science. The degree of B.S. at certain colleges is scarcely more reputable than the degree of B.E.—bachelor of the elements—which is given by one college to the students who fail to obtain any other degree.

The third recommendation of the committee will certainly be approved by college professors. The maximum salary at Amherst is $3,000 and the committee finds that, on the average, professors spend a thousand dollars in excess of their salary. This fact is in itself not significant, for it might mean that one or two professors had large incomes. To make the figures of value the committee should give the number of professors who spend on their living more than three thousand dollars. It is, however, well known that college and university professors receive relatively smaller salaries than men at the head of the other professions, and if a college such as Amherst wishes to obtain and retain for its faculty men of the highest ability, the salaries must be increased.

SCIENTIFIC ITEMS

WE record with regret the deaths of Dr. Samuel H. Scudder, of Cambridge, eminent for his contributions to entomology; of Dr. Stanford Emerson Chaillé, for forty-one years professor of physiology and pathological anatomy in the medical department of Tulane University; of Dr. Edward Burnett Vorhees, professor of agriculture at Rutgers College and director of the New Jersey Agricultural Experiment Station; of Professor William Russell Dudley, professor of botany in Stanford University; of Nathaniel Wright Lord, professor of mineralogy and metallurgy in the Ohio State University; of Mrs. Williamina Paton Fleming, curator of astronomical photographs in the Harvard College Observatory, and of Dr. N. Story Maskelyne, from 1856 to 1895 professor of mineralogy at Oxford.

PROFESSOR E. C. PICKERING, director of the Harvard College Observatory, has been created knight of the Prussian order Pour le mérite. Simon Newcomb and Alexander Agassiz are the only other American men of science on whom this honor has been conferred. —At its annual meeting the American Academy of Arts and Sciences voted to award the Rumford premium to Professor James Mason Crafts "for his investigations in high temperature thermometry and the exact determination of new fixed reference points on the thermometric scale.'

DURING his recent visit to Washington at the time of the annual meeting of the National Academy of Sciences, Sir John Murray presented a fund of six thousand dollars to the academy for the purpose of founding an Alexander Agassiz gold medal which shall be awarded to scientific men in any part of the world for original contributions to the science of oceanography.